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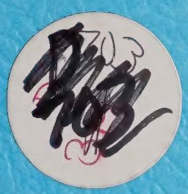
MODEL 45

PHASE JITTER METER



HLI

HEKIMIAN LABORATORIES, INC.

2351 SHADY GROVE ROAD

ROCKVILLE, MARYLAND 20850

INSTRUCTION MANUAL

MODEL 45

PHASE JITTER METER

MANUFACTURED BY

HEKIMIAN LABORATORIES

~~322 N. STONESTREET AVENUE~~ 15825 SHADY GROVE ROAD

ROCKVILLE, MARYLAND 20850

PART NO. 45-014

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SECTION 1.0

INTRODUCTION

1.1 GENERAL DESCRIPTION

The Model 45 Phase Jitter Meter is designed to measure the phase modulation or "jitter", short-term amplitude variations and amplitude drop-outs resulting from signal transmission through a voice frequency communications channel. High speed data transmission of 1200 bits per second and above are particularly sensitive to these parameters which rank in importance with signal-to- noise ratio, impulse noise, frequency response, and envelope delay distortion in determining channel error performance. Phase jitter and amplitude variations may be introduced by the transmission medium and terminating, multiplex, carrier and radio equipments. The ability to measure these important performance parameters and isolate those transmission links or equipments which are causing unacceptable performance is an important and necessary function in maintaining a high grade of service.

The Model 45 Phase Jitter Meter measures peak-to-peak and average phase jitter, phase hits, amplitude hits, amplitude drop-outs, and coincident amplitude/phase hits introduced on a 1.0 kHz carrier transmitted through the voice frequency channel under test. The magnitude of the peak-to-peak and average phase jitter is displayed on a meter while the remaining measurements are made using individual mechanical totalizers.

The unit is completely self-contained and incorporates a transmit test tone oscillator for making loop measurements without additional equipment. End-to-end measurements may be made using a second Model 45 or any

good quality audio osillator as a test tone source. A 60 minute timer is incorporated to allow unattended collection of data over pre-set intervals. When totalized data is not required, flashing indicator lamps may be used in place of the mechanical totalizers. An external jitter output is provided to allow chart recording or spectrum analysis. The phase hit, amplitude hit, coincident phase/amplitude hit, and drop-out threshold outputs are made available through external outputs on the rack mounting model for use in further defining hit and drop-out statistics.

The Model 45 is available in rack panel mounting or portable form. In rack mounting form it occupies 5 1/4 inches of panel height and all input/output connections may be made at rear mounted barrier strips. In its portable form it is self contained in a hinged cover transit case measuring 8" wide, 14" long and 9.5" high.

1.2 SPECIFICATIONS

The mechanical and electrical specifications for the Model 45 Phase Jitter Meter are contained in Table 1-1.

TABLE 1-1

SPECIFICATIONS

INPUT	
Frequency	1000 Hz ± 15 Hz
Level	-30 to + 10 dBm
Impedance	600Ω, 900Ω (Portable only) 10,000Ω (Bridge)
TRANSMIT OUTPUT	
Frequency	1000 Hz ± 2Hz
Level	-20 to 10 dBm
Impedance	600Ω
METER	
P-P or average jitter	0 to 30 degrees (± 1°)
Input/Output Level	-20 to +2 dBm (± 1.0 db)
PHASE HITS COUNTER	
Threshold Levels (peak)	5° steps, 5° to 45° (±1°)
Hit resolution	100 MS
Min. hit duration	4 MS
AMPLITUDE HITS COUNTER	
Threshold levels	± 1,2,3 and 6 db
Hit resolution	100 MS
Min. hit duration	4 MS
DROPOUTS COUNTER	
Threshold level	-15 to -30 dBm (internally adj.)
Resolution	100 MS
Min. Dropout duration	300 MS
COINCIDENCE COUNTER	
Resolution	100 MS
Min. Coincidence duration	1 MS
EXTERNAL JITTER OUTPUT	
Impedance	20,000Ω
Level	100 mv/degree (approxmiately)

EXTERNAL LOGIC OUTPUTS (ALL)	
Impedance	10,000Ω
Level	Inactive 0. vdc Active -10 vdc
TIMER	0-60 minutes
VOLTAGE	105 to 125 VAC, 50-60 Hz
POWER	20 watts
DIMENSIONS	Rack Mounting Unit 5 1/4" high 19" wide 15" deep Portable Unit 8" high 14" wide 9.5" deep (with cover)

SECTION 2.0
INSTALLATION

2.1 GENERAL

The Model 45 Phase Jitter Meter was designed for ease of operation and installation. After the unit has been removed from its shipping container, perform a complete external visual inspection for possible damage. To inspect the inside of the rack mounting unit, remove the seven slotted-head screws retaining the top and bottom covers and perform a visual inspection. To inspect the portable version, remove the two screws along the right and left hand edges of the panel and remove the inner assembly from its transit case. Any damage due to shipping should be immediately reported to the shipping agency.

All internal adjustments have been set at the factory and no futher adjustment is required prior to installation or use of the equipment.

2.2 RACK MOUNTING UNIT INSTALLATION

The unit may be mounted in any standard 19 inch relay rack and requires a standard rack panel height of 5 1/4 inches. Four screws with protective washers should be used in mounting the unit.

Primary power is supplied through the line cord packed with the instrument. This cord is connected to the three-pronged AC recepticle located on the rear panel.

Signal input/output lines may be connected to either the front panel binding posts or the appropriately marked barrier strips on the rear panel of the instrument. Shielded cabeling is recommended for all input/output connections.

Connections to the external phase jitter and logic outputs are made to the appropriately marked barrier strip on the rear panel of the instrument.

When these connections have been completed the unit is ready for operation.

2.3 PORTABLE UNIT INSTALLATION

Primary power is supplied through the line cord packed in the compartmented cover of the transit case. The cover may be opened by operating the two fasteners holding the compartment lid. The cord is connected to the AC receptacle located through the access hole on the right-hand side of the instrument.

Signal input/output lines are connected to the front panel binding posts or the front panel mounted Western Electric 310 jacks. Shielded cabling is recommended for all input/output connections.

Connection to the JITTER output is made using a standard two-circuit tip-sleeve phone plug. The phase hit, amplitude hit, coincident and dropout logic outputs are not available externally on the portable unit.

For fixed station applications, an optional rack mounting shelf is available. This shelf mounts in a standard 19" relay rack and occupies 10 1/2 inches of verticle rack space. The behind the panel depth is 12" which includes storage provisions for the transit case cover.

SECTION 3.0

OPERATION

3.1 GENERAL

This section contains a description of the controls and indicators and operating procedures to be used with the Model 45. Prior to operation be sure that all connections to the instruments are made in accordance with the instructions of Section 2.0, Installation.

3.2 CONTROLS AND INDICATORS

The controls and indicators used in operating the Model 45 Phase Jitter Meter are described in Table 3-1. All controls are located on the front panel. No internal adjustments are required during normal operation. Adjustment procedures for internal controls are contained in Section 5.0, Maintenance

TABLE 3-1

FRONT PANEL CONTROLS AND INDICATORS

Designation	Reference	Function
POWER switch and Indicator lamp	S203 DS 206	Applies AC primary power to the instrument.
INPUT terminals	J201,205, 206,207	Provides input connections for wire leads, clip leads, banana plugs and Western Electric 310 plugs.
INPUT switch	S201	Selects input line terminations of 600 ohms, 900 ohms (portable unit only), or bridging (10,000 ohms).

Designation	Reference	Function
METER switch	S204	Selects the input to the front panel meter, measures input/output level, peak-to-peak jitter, average jitter, reference set level and relative frequency of the phase-locked oscillator.
FREQ control	R202	Adjusts the frequency of the phase-locked oscillator to coincide with the input frequency.
METER	M201	Displays the parameter selected by the meter switch.
LEVEL SET control	R223	Sets input signal at an internal reference level of 0 dBm.
PEAK DEGREES switch	S205	Selects the threshold to degrees (peak) which must be exceeded by the phase jitter to be totalized on the phase kits counter.
PHASE Hits counter	L203	Totalizes the number of phase impulses exceeding the threshold setting.
PHASE HITS indicator lamp	DS204	Flashes when a phase hit is detected when S207 is in the FLASH position.
±DB Amplitude hits switch	S206	Selects the threshold in db which amplitude fluctuations must exceed before being totalized on the amplitude hits counter.
AMPLITUDE HITS counter	L204	Totalizes the number of amplitude hits exceeding the level set on S206
AMPLITUDE HITS Indicator lamp	DS203	Flashes when an amplitude hit is detected when S207 is in the FLASH position.

Designation	Reference	Function
COINCIDENCE counter	L205	Totalizes the number of coincident phase/amplitude hits which exceed their respective thresholds. Will count multiple hits from one source during an extended duration hit from the other source.
COINCIDENCE indicator lamp	DS202	Flashes when coincident phase/amplitude hits are detected when S207 is in the FLASH position.
DROPOUTS counter	L206	Totalizes the number of dropouts which fall below the internally set level (typically -18 dBm) for longer than 300 milliseconds When a dropout has occurred all other counters/indicators are inactivated.
DROPOUTS indicator lamp	DS201	Flashes when a dropout has occured and S207 is in the FLASH position.
TIMER	S202	Automatic timer to allow unattended accummulation of data for known time intervals. Continuous operation provided in HOLD position.
TIMER indicator light	DS205	Glows when the timer is in the ON position.
COUNT FLASH switch	S207	Selects the operation of either the counters or indicator lamps.
OUTPUT terminals	J202,208, 209,210	Provides connection to the transmit oscillator, for wire leads, clip leads, banana plugs and Western Electric 310 plugs.
OUTPUT LEVEL control	R215	Controls the level of the transmit oscillator output.

3.3 OPERATING PROCEDURES

3.3.1 INPUT/OUTPUT LEVEL

To insure proper operation of the instrument, the input and output (if used) levels should be checked prior to a measurement. This is performed by selecting the appropriate position of the meter switch. The meter reads in dBm for all input terminations. For inputs below -20 dBm (the instrument will operate down to -30 dBm input levels), a separate more sensitive level meter should be used. The output level is adjusted using the OUTPUT LEVEL control.

3.3.2 LEVEL SET ADJUSTMENT

After determining that the proper input signal level is present, the level set adjustment must be made. Place the meter switch in the LEVEL SET position and adjust the LEVEL SET control for a reading of 0 dBm. This adjusts the instrument's internal reference level for optimum operation of the phase jitter and amplitude sensitive circuitry.

If long term input level changes during the test exceed ± 3 db the LEVEL SET control should be readjusted.

3.3.3 FREQUENCY ADJUSTMENT

After proper input/output levels have been established the internal reference phase locked/oscillator must be "locked" to the incoming carrier frequency. This is performed by placing the meter switch in the FREQ position and adjusting the FREQ control for a meter reading at the FREQ SET mark (half scale). Proper operation must be verified by rotating the FREQ control over its entire range and noting a corresponding deflection of the meter over approximately 80% of its scale. It is

possible that the reference oscillator will lose lock at the extreme settings of the FREQ control. This will be indicated by an oscillation of the meter needle, which decrease in frequency as the locked oscillator condition is approached. When phase lock is obtained, the oscillation will stop and the meter will read near one end of its scale. As rotation of the FREQ control is continued, the meter will move to the FREQ SET mark. When this has been verified, set the meter to the FREQ SET mark. This should occur near the mid-range of the FREQ control. Valid measurements may now be made.

If the input frequency is offset from the nominal 1.0 kHz, but still within the range of the instrument, the FREQ control must be offset from its mid-range position to set the meter on the FREQ SET mark. If the FREQ SET mark cannot be reached, the test signal frequency error is excessive and the transmit frequency should be checked and adjusted.

When the test tone frequency is outside the range of the instrument, the FREQ control will have little or no effect on the meter indication. The meter will remain near the FREQ SET mark regardless of the FREQ control position. When this indication is obtained, independent measurements should be made to verify the test signal frequency.

3.3.4 AVERAGE PHASE JITTER

The average phase jitter is measured by placing the meter switch in the AV JITTER position and reading the value on the meter scale. A maximum value of 30 degrees may be measured.

3.3.5 PEAK-TO-PEAK PHASE JITTER

Peak-to-peak jitter is measured by setting the meter switch to the P-P JITTER position. Peak-to-peak phase jitter values up to 30 degrees may be measured.

3.3.6 PHASE HITS MEASUREMENT

The phase jitter will occasionally show large, rapid variations in phase. These phase impulses, or "hits" may be totalized using the phase hits counter. The counter operation is controlled by the TIMER and the FLASH-COUNTS switch.

The phase threshold which a hit must exceed before it is totalized is set by the PEAK DEGREES switch. If the switch is set at 25 degrees, any positive or negative phase hit which exceeds 25 degrees for more than 4.0 milliseconds will result in an additional count being added to the total displayed on the counter. The counter may be reset to zero using a small toggle lever located on its front bezel. Note that the counter measures peak phase hits as differentiated from the peak-to-peak jitter measured by the meter.

3.3.7 AMPLITUDE HITS MEASUREMENT

The test tone will frequently show rapid variations in amplitude. These variations or hits may be totalized using the amplitude hits counter. The counter operation is controlled by the TIMER and the COUNT-FLASH switch.

The amplitude threshold which a variation must exceed before it is totalized is set on the AMPLITUDE HITS switch. If the switch is set at $\pm$ 3 db, any amplitude variation either plus or minus which exceeds this level for more than 4.0 milliseconds will result in an additional count being added to the total displayed on the counter. The counter may be reset to zero using the small toggle lever located on its front bezel.

Threshold levels of $\pm$ 1, 2, 3 and 6 db are provided.

3.3.8 COINCIDENT PHASE/AMPLITUDE HITS MEASUREMENT

To provide insight into the mechanism causing the phase and amplitude hits a coincidence counter is provided which totalizes simultaneous phase and amplitude hit occurrences. No controls are associated with this indicator and its operation is controlled by the TIMER and the COUNT-FLASH switch.

The coincidence counter will totalize multiple hits from one source if an extended duration hit is occurring on the second source. If during a long duration amplitude hit several phase hits occur these individual phase hits will be totalized on the coincidence counter. Thus it is possible for the coincidence counter to indicate a number of coincident hits which exceeds either value shown on the phase and amplitude hit counters.

The counter may be reset to zero using the small toggle lever located on its front bezel. When the COUNT-FLASH switch is in the FLASH position, the counter is disabled and coincidence hits are indicated by a flashing of the indicator lamp.

3.3.9 DROPOUT MEASUREMENT

The number of amplitude dropouts on the circuit is measured by the dropouts counter. The dropout threshold level may be internally set between 15 and 30 db. After a dropout has occurred, the amplitude hits, phase hits and coincidence counters are disabled until the input signal again exceeds the dropout threshold.

For accurate dropout detection the LEVEL SET control must be adjusted to provide a 0 dBm indication on the meter in the LEVEL SET position with the nominal test tone level applied.

To be detected as a dropout the amplitude variation must exceed the dropout threshold for a period exceeding approximately 300 milliseconds. Amplitude variations of less than this duration or amplitude will not be counted as dropouts.

The dropout threshold is set internally as described in Section 5, Maintenance. This is set at the factory at -18 dB in accordance with established Bell System practices.

The counter may be reset to zero using the small toggle lever located on its front bezel. When the COUNT-FLASH switch is in the FLASH position the counter is disabled and dropouts are indicated by a flashing of the indicator lamp.

3.3.10 TIMER OPERATION

Operation of the counters and indicator lights is controlled by the timer. For timed measurements the timer is set to the desired number of minutes. At the end of this period the timer reaches zero and counter operation is inhibited. For continuous operation the timer is rotated clockwise to the HOLD position.

When the timer is in the ON condition the COUNT-FLASH switch is used to select either the counters for totalized information or the flashing indicator lights. It is recommended that the FLASH position be used when recorded data is not to be gathered to reduce mechanical wear in the counting units.

NOTE

The timer must be turned past 10 minutes to fully activate its spring mechanism. For durations less than 10 minutes, the timer knob may then be returned to the desired interval. If this is not done, intervals of less than 10 minutes will not be accurately timed.

3.3.11 EXTERNAL PHASE JITTER OUTPUT

The external PHASE jitter output makes available for external chart recording or spectral analysis the jitter output of the phase detector. Its output impedance is approximately 20,000 ohms and it should only be connected to high imput impedance devices. The open circuit voltage at this point is approximately 100 millivolts/degree of phase jitter. The jitter energy lies between 10 and 250 Hz as determined by the internal low pass and high pass filters incorporated in the instrument.

3.3.12 EXTERNAL THRESHOLD LOGIC OUTPUTS

Logic outputs for the threshold detectors associated with the phase hits, amplitude hits, phase/amplitude coincident hits, and dropouts are provided on a rear mounted barrier strip, in the rack mounted version. When a threshold has been exceeded the logic level drops to a -10 volts DC. The duration of the pulse is equal to the time the threshold level is exceeded.

These outputs are not made available on the portable unit.

SECTION 4.0

THEORY OF OPERATION

4.1 GENERAL

The Model 45 Phase Jitter Meter is entirely solid state and makes extensive use of integrated circuit differential operational amplifiers as well as conventional discrete components. The design makes use of modern design techniques in both the analog and digical circuitry.

A simplified block diagram of the phase jitter meter is shown in Figure 4-1. The incoming test tone signal is first terminated in the desired impedance prior to the input amplifier. The LEVEL SET control is used to set the gain of the input amplifier to provide a fixed reference level at its output. This signal is then fed to the two major functional blocks of circuitry, one associated with the phase jitter measurement and the other with the amplitude, coincidence and dropout measurements.

The signal from the input amplifier is connected to the input limiter of the phase jitter detector circuitry. The output of the limiter is a square wave replica of the input signal zero crossings and becomes one input to the digital phase detector. The phase detector compares this signal to the phase-locked reference oscillator and generates DC pulses, whose width are proportional to the phase difference. These pulses are then changed to a DC voltage proportional to the phase difference by the 300 Hz lowpass filter. This output is used to control the phase-locked reference oscillator which has a loop bandwidth of approximately 5 Hz. The filtered phase detector output is also applied to an AC coupled amplifier which removes the DC component from

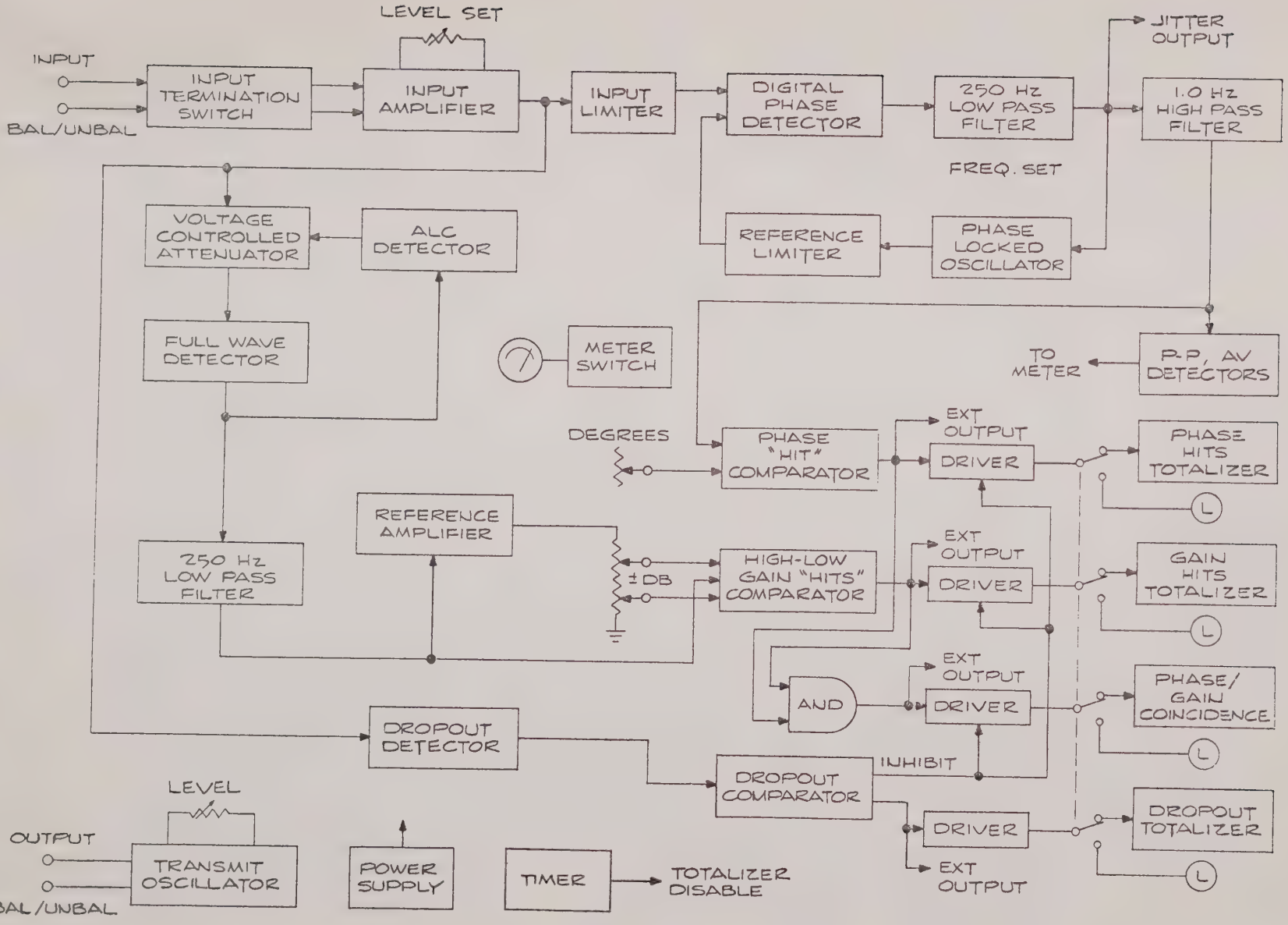

FIGURE 4-1 PHASE JITTER METER BLOCK DIAGRAM

the phase detector output. This jitter signal is then full-wave rectified and applied to the average and peak-to-peak metering circuit.

The phase impulse counter uses an adjustable threshold detector to detect phase excursions above a pre-set threshold. Each time a positive or negative phase excursion exceeds this threshold a pulse is generated which drives the phase hits counter or indicator lamp.

The signal applied to the amplitude measurement circuitry is processed by a wide dynamic range automatic level control (ALC) circuit incorporating a voltage controlled attenuator, full wave rectifier and a peak detector. The output level of this circuit remains constant within $\pm$ 2 db for input range variations of 30 db. Level corrections are made with a time constant of approximately 10.0 seconds. The output of the full wave detector is filtered in a 250 Hz lowpass filter and applied to the reference amplifier and the high/low gain hits comparator. This circuit detects amplitude variations exceeding the preset threshold values and generates a pulse signal which drives the amplitude hits counter or lamp.

Prior to the ALC the signal is monitored by the dropout detector and dropout comparator. When the absolute signal level drops below the comparator threshold level a pulse is generated and activates the dropout counter or lamp. A dropout must exist 300 milliseconds before recognition is made. During a dropout period all the other counters and lamps are disabled until the signal level rises above the dropout threshold.

The outputs of the phase and amplitude hit comparators are combined in an "and" gate to generate the driving pulse for the amplitude/phase coincidence counter. When both hits are simultaneously present for 1 millisecond

or longer a coincidence hit pulse is generated and fed to the counter or indicator light.

The stable 1.0 kHz transmit test tone oscillator incorporates a line amplifier which is transformer coupled to the balanced transmit output.

The meter switch allows the meter to monitor the input or output test tone levels, the set level reference valve, the outputs of the peak-to-peak or average jitter detectors and the control loop of the phase locked reference oscillator.

Power for the instrument is supplied by an electronically regulated dual power supply providing +15 and -15 volts DC from which all operating voltages are derived.

A 60 minute timer with a "hold" position controls the power to the counters and allows unattended measurements to be performed.

The following sections describe in detail the circuit operation of the Model 45 Phase Jitter Meter.

4.2 DETAILED CIRCUIT OPERATION

4.2.1 LINE INPUT

The input signal is connected using the three-way binding posts, the Western Electric 310 jack (portable unit only) or the rear mounted barrier strip (rack mounting unit only). Both balanced and unbalanced signals may be accommodated. The line input is terminated by the input switch S201. DC line currents are blocked by the input coupling capacitors C401, 402, and transient voltage protection is provided by diodes D401, thru 404. The differential operational amplifier IC401A provides conversion of the unbalanced input signal to a balanced output signal with a gain controlled by the LEVEL SET control

R223. Amplifier phase compensation is provided by R405, C403, 404. The LEVEL SET control is adjusted to provide a OdBm meter indication with the meter switch in the LEVEL SET position. The output of this amplifier is used to feed both the phase jitter and amplitude detection circuitry.

The input level meter is connected through a separate DC blocking capacitor C135 to minimize phase shift introduced by the switching of the meter load across capacitors C401, 402.

4.2.2. PHASE JITTER INPUT CIRCUITRY

The differential operational amplifier IC-101A operates as an open loop gain zero crossing detector with DC stabilization provided by R103, 104 and C104. Amplifier phase compensation is provided by R106 and C108.

4.2.3 DIGITAL PHASE DETECTOR

The output from IC-101A and the phase locked reference oscillator output from IC-101B are connected to the two inputs of the digital phase detector. Transistors Q101 and Q102 and the associated components form an "exclusive-or" gate which provides a bipolar output pulse whose width is proportional to the phase difference (zero crossings times) of the two inputs. The back-to-back zener diodes D107, 108 provide a constant amplitude pulse to the following circuitry.

4.2.4 LOW PASS FILTER

The carrier frequency present at the output of the digital phase detector is removed and the upper limit of the phase jitter spectra determined by the low pass filter consisting of IC-102B and its related components. This filter provides a three-pole butterworth response using active filter design techniques. The filter elements consist of R113, 114, 115, 117 and C105, 106

110. Components R116 and C103, 107 are phase compensating networks for the operational amplifier.

4.2.5 PHASE LOCKED REFERENCE OSCILLATOR

The output of the low pass filter is a DC voltage proportional to the instantaneous phase difference between the input and reference signals. This voltage is filtered by the network consisting of R162, 163, and C124 to provide an overdamped phase lock loop response characteristic. The filtered voltage controls a conduction angle reactance modulator consisting of emitter follower Q104 and C125, D119. This circuit effectively varies the capacitance across the oscillator tank circuit consisting of L101 and C129, 128. The oscillator frequency may be varied by the front panel FREQ control and its associated capacitor C126. The oscillator output is connected to the input of the reference limiter IC-101B which furnishes the limited reference signal to the digital phase detector.

The average DC value of the digital phase detector output will be zero when the phases of the input and reference signals are properly related. This is monitored by the meter using multiplier resistor R118 and bias resistors R119, 120.

4.2.6 AC COUPLED AMPLIFIER AND FILTER

The output of the low pass filter is connected to an AC coupled amplifier filter consisting of IC-102A and its related components. C140 provides an additional filter section and R123 and C112, 113 provide phase compensation for the operational amplifier. The output of IC-102A is applied through isolation resistor R126 to the external jitter output.

4.2.7 AVERAGE DETECTOR

The average value of the phase jitter is measured by performing a full wave rectification of the phase jitter signal and applying this to the metering circuit. The full wave detector consists of IC-103A, 104B. IC-103A is used as a half wave rectifier with feed back to eliminate the effects of the diode rectifier offset voltages. The negative half wave rectified signal is summed through R132 and R131 with the original input signal and the resulting full wave rectified waveform is amplifier by IC-104B. This circuit provides a highly stable, precision full wave rectifier, independent of diode offset characteristics. Its output is applied to the meter through R138 and the calibration resistor R139. The meter displays the average value of the rectified phase jitter signal.

4.2.8 PEAK-TO-PEAK DETECTOR

The peak-to-peak detector IC-103B utilizes the output of IC-103A to provide a signal compensated for diode offset voltages in both the positive and negative direction. IC-103B is a unity gain driver amplifier for the positive peak detector D111, R143, C120 and the negative peak detector D112, R144, C121. The outputs of these peak detectors are applied to the meter through resistor R146 and the calibration resistor R145. The detector time constant provides peak detection of repetitive signals down to the low frequency cutoff of the phase jitter signal.

4.2.9 PHASE HITS DETECTOR

The full-wave rectified jitter signal is applied to a differential amplifier threshold detector IC-104A which compares this signal to the threshold level set by the PEAK DEGREES switch S205. The output of the amplifier

remains at a positive value until the phase jitter signal exceeds the threshold level. When this occurs, the output abruptly changes to a negative voltage and when the input falls back across the threshold voltage, the output returns to the positive level.

The hit transition is processed by a four millisecond "time out" circuit consisting of Q502 and IC-501A located on PC board HLI TO-1. A positive voltage at the base of Q502 clamps the r.c. time-constant circuit R508, C502 to ground, and results in a positive voltage output from the trigger amplifier IC-501A. When a phase hit occurs, Q502 is opened allowing C502 to charge towards the supply voltage. The time constants are arranged so the capacitor voltage crosses the trigger amplifier threshold in four milliseconds resulting in a change of state of the trigger amplifier output. This change is used to drive the phase hits multivibrator and logic output. If the phase hit is terminated prior to the four millisecond interval, the capacitor is immediately clamped to ground terminating its charging cycle. Thus, phase hits of less than four millisecond duration will not trigger the phase hits multivibrator.

4.2.10 AUTOMATIC LEVEL CONTROL CIRCUITRY

The automatic level control circuitry consists of the amplifier and full wave rectifier IC401B, 402A, the peak detector D409, and the FET voltage controlled attenuator Q421, R406. These circuits provide output variations of less than $\pm$ 2 db for a 30 db range of input levels.

The input signal is applied to R406 which forms a voltage divider with the voltage controlled resistance of the FET transistor Q421. This attenuated voltage is then applied to the full wave rectifier IC401B which

incorporates a bridge rectifier, D405 thru 408, in its feedback loop. Amplifier DC stabilization is provided by R413 and C408 and phase compensation by R407 and C406, 407. This circuit arrangement automatically compensates for the diode offset voltages. The positive and negative waveforms are summed and inverted in the unity gain amplifier, IC402A, which provided at its output a full wave rectified replica of the input signal at IC401B. The full wave rectified signal is applied to the peak detector D409, C411 which develops the DC control voltage for the voltage controlled attenuator, transistor Q421. A DC offset control R418 is provided for setting the operating point of Q421. Its adjustment is covered in Section 5, Maintenance. The 10 second time constant of the ALC loop is provided by R416 and C405.

4.2.11 LOW PASS FILTER

The carrier frequency present at the output of the full wave detector is removed and upper limit of the amplitude variation is determined by the lowpass filter consisting of IC402B and its related components. This filter provides a 250 Hz 3 pole butterworth response using active filter design techniques. The filter elements consist of R419, thru 422, and C412, thru 414. Components R423 and C416, 415 are phase compensating networks for the operational amplifier.

4.2.12 AMPLITUDE HITS DETECTOR

The amplitude hits detector consists of dual threshold detectors set to activate whenever an increase or decrease in signal level occurs which exceed the $\pm$DB switch setting. The outputs of these detectors are then combined and used to drive the "time out" circuit followed by the

amplitude hits counter or indicator lamp.

The amplitude threshold detectors IC-404A, B compare the output of the lowpass filter containing the short-term amplitude variations with a long-time constant reference voltage generated by the reference amplifier IC-403A. Decision hysteresis is provided in the threshold detectors by resistors R428, 429, and R430, 431 respectively. Phase compensation is provided by C421, 422 and 423, 424.

The reference amplifier obtains the long-term average of the lowpass filter output through R424 and C420. This is then applied to the input of amplifier IC-403A and amplified by a factor of 2. The gain is controlled by the resistor divider network consisting of R425, 426 and 216 thru 222. The $\pm$DB switch S206 selects the voltages on this divider chain corresponding to $\pm$ 1, 2, 3 or 6 db levels. These voltages then form the reference inputs to the amplitude threshold detectors.

The outputs of the threshold detectors are combined by diodes D411, 410 and applied to the four millisecond "time out" circuit consisting of Q501 and IC-501B located on PC board HLI TO-1. Its operation is identical to the phase hits "time out" circuit discussed in section 4.2.9, except a hit is indicated by a positive rather than a negative voltage. The "time out" circuit output is connected to transistors Q401, 402 which furnish the driving signals to the one shot multivibrators driving the amplitude hit and coincident hit indicators respectively.

The external logic outputs are obtained from the collectors of these driver transistors through isolating resistors R469, R450.

4.2.13 DROPOUT DETECTOR

The dropout detector is activated when the input signal drops a fixed number of db below the input reference level existing at the time the LEVEL SET control was adjusted.

The dropout threshold detector IC-403B is fed by the high stability wide dynamic range peak detector consisting of Q420, 419. These two transistors form a long tail pair peak detector circuit having excellent detector linearity, dynamic range, and DC level stability. The capacitor C417 determines the dropout detector time constant which filters out dropouts having durations less than 300 milliseconds. The dropout signal is then fed to one input of the threshold detector where it is compared against the threshold level set by R434. This is factory set for a level of -18 db; however, levels between -15 and -30 db may be accommodated by the proper adjustment of R434.

The output of the dropout threshold detector is applied to the driver transistor Q403, and the inhibit transistors Q410, 413, 416 which inhibit all the one shot multivibrators during dropout intervals. The external dropout logic output is obtained from the collector of Q403 through isolation resistor R438.

4.2.14 PHASE/AMPLITUDE COINCIDENCE DETECTOR CIRCUITRY

Coincidence between the phase and amplitude hit threshold detectors is determined by transistor Q402. This transistor responds only when both inputs are positive and triggers the coincidence multivibrator thru C429. The external coincidence logic output is provided through isolating resistor R450.

4.2.15 COUNTER DRIVER CIRCUITRY

The totalizer driver circuitry is identical for the phase hits, amplitude hits, coincident and dropout counters and indicator lamps. A single explanation will be given for the amplitude hits totalizer and this may be used with appropriate substitution of component designations for the other driver circuits.

The transition in the threshold detector outputs is amplified in the driver transistor Q401 and applied to the input differentiating capacitor C431. The positive going edge is removed by D418 and the negative going pulse is applied through R470 to the multivibrator consisting of Q414, 415. The multivibrator provides the 50 millisecond on-pulse followed by a 50 millisecond off-time which is required for the mechanical counter operation. The multivibrator output is amplified by Q417 which feeds the counter driver Q418. Transient suppression for the output driver is provided by R479 and D419.

The output may drive either the counter L204 or the indicator lamp DS203 depending on the position of the COUNT-FLASH switch S207.

Inhibiting transistor Q416 is included in all except the dropout detector driver and inhibits the multivibrator operation when a positive signal is obtained from the dropout threshold detector. The inhibit transistor Q413 for the phase hits multivibrator is located on the HLI-45 board.

4.2.16 TIMER

The mechanical timer S202 controls the DC voltage to the counters and indicator lamps thru T201. When the timer is "on" the timer on-off lamp DS205 is illuminated.

4.2.17 METER CIRCUIT

Input/output levels, peak-to-peak and average phase jitter and frequency are monitored using the front panel mounted 50 microamp meter. The meter input is selected by the meter switch S204. For input/output level monitoring, a bridge rectifier consisting of D201, 202 and R203 thru 205 is used to rectify the audio voltages.

4.2.18 TRANSMIT OSCILLATOR

The transmit oscillator Q111 frequency is determined by the LC tank circuit, L102, C131. Its operation is similar to the phase locked reference oscillator. Its output is connected to the output LEVEL control R215 which is connected to the push/pull emitter coupled amplifier, Q105, 106. This amplifier provides a low distortion -20 to + 10 dBm, 600 ohm test tone source for use in back-to-back and loop testing.

4.2.19 POWER SUPPLY

The power supply contains separate +15 and -15 volt DC regulator sections. It provides .01% line and 0.05% load regulation, and has a temperature coefficient of 0.02% per degree C. Noise and ripple on the power supply output is 1.0 millivolt rms maximum.

The negative rectified voltage from D303, 304, and C302 is regulated by the series power transistor Q301. The regulated voltage is compared against the zener diode reference D306 and the difference is amplified by Q305, 308, 304, to provide the driving signal to Q301.

The positive voltage from D301, 302 and C301 is regulated by Q302. The reference is obtained from the negative supply and differences are amplified by Q303, 305, 306, to provide the driving signal to Q302.

SECTION 5.0

MAINTENANCE

5.1 MAINTENANCE PHILOSPHY

Maintenance procedures for the Model 45 are divided into preventive and corrective classifications. Preventive maintenance consists of the routine performance checks which may be made using the front panel controls of the instrument. Corrective maintenance covers the symptom analysis, trouble shooting, repair, and recalibration of the instrument.

5.2 PREVENTIVE MAINTENANCE

5.2.1 GENERAL

The preventive maintenance procedures described in the following sections are used by the operator and maintenance personnel to verify proper instrument operation using the front panel controls. If proper operation is not achieved see Section 5.3 for corrective maintenance procedures.

Periodic cleaning, lubrication or inspection is not required.

All of the following routine tests are made using the internal test oscillator as a signal input. Connections between the OUTPUT and INPUT terminals (red) may be made using clip leads or an appropriate test cord.

5.2.2 INPUT/OUTPUT LEVEL CHECK

Place the meter switch in the OUTPUT LEVEL position and verify that the output level may be adjusted over a -20 to a + 2 dBm range. Set the

level at 0 dBm on the OUTPUT LEVEL position and then monitor the input level. The input reading should agree within ±0.5 dB of the output level reading.

Absolute calibration of the internal level meter may be checked by comparison with an external standard meter connected in parallel across the INPUT terminals.

Place the meter switch in the SET LEVEL position and verify that the SET LEVEL control can be adjusted to provide a 0 dBm reading on the meter.

5.2.3 JITTER MEASUREMENT CHECK

Place the meter switch in the FREQ position and adjust the FREQ control as described in Section 3. Verify that both the P-P JITTER and AV JITTER positions of the meter switch indicate less than 1.5 degrees. A detailed calibration procedure of peak-to-peak and average phase jitter is contained in Section 5.3.4.

5.2.4 PHASE HITS CHECK

Place the timer in the HOLD position and the phase hits PEAK DEGREES switch in the 5 DEGREE position. Vary the FREQ control rapidly and the totalizer should accumulate phase impulse counts.

5.2.5 AMPLITUDE HITS CHECK

Place the meter switch in the INPUT LEVEL position and adjust the output LEVEL control for a 0 dBm reading with the input in the BRIDGE position. Place the meter in the LEVEL SET position and adjust the LEVEL SET control for a 0 dBm reading. Changing the input switch between the BRIDGE and 600 OHM positions will result in approximately a 6 dB input level change. Place the timer in the HOLD position and verify that amplitude hits

are totalized in the 1, 2, and 3 dB positions of the ± DB switch as the INPUT switch is changed back and forth between the 600 OHM and BRIDGE positions.

5.2.6 PHASE/AMPLITUDE COINCIDENT HITS CHECK

With the instrument adjusted as described in Sections 5.2.2 and 5.2.3 place the DEGREES switch in the 5° position and the ± DB switch in the 2 DB position. Verify that when the INPUT switch is changed back and forth between BRIDGE AND 600 OHMS and the FREQ control is simultaneously varied that both phase, amplitude and coincident hits are detected and indicated. Placing the DEGREES switch at a level where phase hits are no longer detected or alternately placing the ± DB switch at a threshold level of 6 dB should cause the coincident indications to stop.

5.2.7 DROP-OUTS CHECK

With the instrument adjusted in accordance with Section 5.2.2 remove the input signal (both input leads must be removed simultaneously). A drop-out indication should occur approximately 1/3 second after removal of the input signal.

5.3 CORRECTIVE MAINTENANCE

5.3.1 TROUBLE SHOOTING

This section covers the sympton analysis, circuit level isolation and calibration procedures of the Model 45.

No specialized mechanical assembly or disassembly procedures are required. Accepted practices should be followed when repair is undertaken on main frame components or the printed circuit boards.

Recommended trouble shooting techniques are based on signal tracing methods where a known input signal is supplied and the level and waveform are verified as the signal progresses through the circuitry. Typical test equipment required to perform the trouble shooting procedures are listed in Table 5-1.

TABLE 5-1

MAINTENANCE TEST EQUIPMENT

DESCRIPTION	TYPICAL MODEL NUMBER
Audio oscillator (2)	HP 204C
Resistor network	See text
AC voltmeter	HP 400EL
Oscilloscope, single channel, 1 MHz frequency response	Tektronix 323
Multitester	Simpson 260

5.3.2 SYMPTOM ANALYSIS

The preventive maintenance checks of Section 5.2 are used to isolate the area in which malfunction occurs. Table 5-2 summarizes possible fault locations for each of the preventive maintenance tests.

5.3.3 CIRCUIT LEVEL TROUBLE SHOOTING

The following sections describe the general procedures to be used in locating malfunctions. Where appropriate, performance standards i.e., voltage levels or waveform descriptions are provided to assist in the trouble shooting procedures.

TABLE 5-2

SYMPTOM ANALYSIS

PREVENTIVE MAINTENANCE TEST	PROBABLE TROUBLE LOCATIONS
1. No response from any test	a. AC power cord b. Internal AC wiring or POWER switch S203 c. Power supply
2. Input/Output level check	a. Q105,106,111, R215 b. Meter switch S204 or meter rectifiers D201, 202 c. Meter M201
3. Jitter measurement check	
Unable to "lock" frequency	a. Q103, 111 oscillator frequency incorrect b. IC-101_{AB}, 102_{B}, 401_{A}, Q101,102,103,104
No Av. jitter indication	a. IC-102_{A},103_{A}, 104_{B}
No P-P jitter indication	a. IC-103_{B}, D111, 112
4. Phase hits check	a. Totalizer power supply S202; T201; D115 thru D118 b. IC-104A; 501A; Q107, 108,109, 110 , 502 c. PEAK DEGREES switch S205 d. Totalizer L203
5. Amplitude hits check	
Cannot set LEVEL SET	a. IC-401_{A}, R223
Improper threshold detection	a. IC-401_{B},402,403_{A},404
No indication	a. IC-501_{B},Q414 thru Q418, 501 b. L203, DS204, S202

TABLE 5-2 (continued)

SYMPTOM ANALYSIS

PREVENTIVE MAINTENANCE TEST	PROBABLE TROUBLE LOCATIONS
6. Phase/Amplitude Coincidence check	a. Phase hits ciruitry (see 4) b. Amplitude hits circuitry (see 5) c. Q402, 408 thru 412 d. L205, DS202, S202
7. Dropout check	a. Q419, 420, IC-403$_B$ b. Q403 thru 407 c. L206, DS201, S202

5.3.3.1 TEST TONE OUTPUT CIRCUITRY

The output test tone oscillator is best checked using an oscilloscope. Under normal operation a 12 volt peak-to-peak sine wave should be seen at terminal 44-R and at 44.S with the OUTPUT LEVEL control R215 in the full clockwise position. If no outputs are seen check Q111. The tank inductor L102 should be checked for continuity and the tuning capacitor, C131, should be checked for shorts.

If no output is seen across terminals 44-P, 44-Q, check Q105, 106 and T101.

5.3.3.2 INPUT CIRCUITRY

The input circuitry is most easily checked using a OdBm 1.0 kHz input test signal. With this test signal verify that the LEVEL SET control R223 may be adjusted to provide 0 dBm at the output (pin 2) of IC-401A. If 0 dBm cannot be obtained check diodes D401 through D404 for shorts. If the diodes are good replace IC-401A.

With this test signal verify that a $\pm$ 15 volt square wave at the same frequency is present at the output (pin 2) of IC-101_A. If a square wave is not seen at this output, check IC-101_A.

The input level meter may be checked using the same input signal. The INPUT/OUTPUT level meter position should read within $\pm$0.5 dB of the standard level as measured by an external reference voltmeter. Check R203 through 205 and D201, 202 if this accuracy is not obtained.

5.3.3.3 PHASE-LOCK OSCILLATOR

The phase-lock oscillator circuit incorporates the phase detector Q101, 102, a high pass filter IC-102_B, a reactance modulator Q104, an LC

oscillator Q103 and the reference limiter IC-101_B.

With no input signal check for a 10 volt or greater peak-to peak sine wave at pin 8, of IC-101_B and a $\pm$ 15 volt volt square wave at pin 12 of IC-101_B. Verify that the frequency is 1000Hz $\pm$ 5 Hz (adjust FREQ control for proper frequency). If no waveforms are present check Q103 and IC-101_B.

Connect a 1.0 kHz test signal to the INPUT and with an oscilloscope verify that a $\pm$6 volt pulse train is present at the junction of R111-112 with the instrument in the frequency "locked" condition. The pulse widths are a function of the input and reference signals phase relationship. Place the instrument in an "out-of-lock" condition and monitor the output level of IC-102_B (pin 12) with an oscilloscope. The output should vary over a range of approximately $\pm$ 6 and will appear as an isosceles wave at the "beat" frequency. If the output of IC-102_B remains constant in the "out-of-lock" condition replace IC-102. If this output is proper yet frequency "lock" cannot be obtained check Q104.

5.3.3.4 PEAK-TO-PEAK AND AVERAGE PHASE DETECTOR

The output of IC-102_B is AC coupled and then amplified and filtered in IC-102_A with a gain of 2. The gain may be verified using an oscilloscope.

Operation of the full wave rectifier IC-103_A - 104_B may be verified using the 11.5° p-p jitter calibration signal, (see Section 5.3.4.4) and monitoring the waveform at the output of IC-104_B. This should be a full wave rectified replica of the output of IC-102_A. If no output or a fixed level of $\pm$ 15 volts is measured replace both IC-103 and IC-104.

The output of IC-103_A is used to drive the peak-to-peak detector and its unity gain buffer amplifier IC-103_B. Verify with an oscilloscope that the output of IC-103_B (pin 12) matches its input from IC-103_A (pin 2). Under the test conditions of a 11.5° peak-to-peak jitter input, DC voltages of approximately 3 volts will be measured on the load side of D111 or D112.

5.3.3.5 PHASE IMPULSE DETECTOR

A Schmidt trigger configuration of IC-104_A is used to detect phase variations which exceed the threshold set by S205. When operating properly the output of IC-104_A (pin 2) will change from + 15 volts to - 15 volts whenever the input signal at R147 exceeds the DC level established by the resistor divider chain of S205. Oscilloscope observations of DC levels and waveforms can be utilized to verify operation of the detector circuit using the 11.5° p-p jitter calibration signal of Section 5.3.4.4 with S205 set in the 5° threshold position. The detector output is connected to the Time Out Board, where Q502 clamps C502 to ground when + 15 VDC is applied to pin D. Verify with an oscilloscope that C502 charges towards + 15 VDC during the hit period. If this does not occur, replace Q502. By increasing the level of oscillator #2, the hit period may be extended beyond 4.0 milliseconds at which point a + 15 volt to - 15 volt transition will take place at the output of IC-501_A (pin C) for the remainder of each hit period. If this does not occur replace IC-501. This output is differentiated by C122 and the negative going edge used to trigger the one shot multivibrator which drives the mechanical totalizer L203. Verify with an oscilloscope that the negative trigger spike across D113

exceeds 10 volts.

5.3.3.6 AUTOMATIC LEVEL CONTROL (ALC)

The automatic level control consists of the voltage controlled attenuator Q421, R406, a full wave rectifier IC-401_B, IC-402_A and a peak detector D409, C411. With a 1.0 kHz test-tone input adjust the LEVEL SET control R223 for an 0 dBm meter reading in the LEVEL SET POSITION. Using a DC volt meter check the voltage at the junction of diode D409 and C411. This voltage should be between + 2 and + 3.5 volts DC. If this voltage is not obtained replace Q421 and readjust R418 in accordance with the calibration procedures of Section 5.3.4. If the correct DC voltage is still not obtained replace IC-401_B and IC-402_A.

Verify with an oscilloscope that a full wave rectified sine wave appears at the output (pin 2) of IC-402_A. The peak value of the full wave rectified sine wave should be approximately 3 volts. Using the voltmeter verify that approximately - 1 volt DC appears at the output (pin 12) of IC-402_B. If no sine wave or if $\pm$ 15 volts is seen replace IC-402.

5.3.3.7 AMPLITUDE HITS DETECTOR

The amplitude hits detector consists of the reference amplifier IC-403_A, the positive hits detector IC-404_A, the negative hits detector IC-404_B and combining diodes D410, 411.

Using the 0 dBm test signal measure the voltage appearing at pin 6 of IC-403_A. The output voltage (pin 2) of this amplifier should be twice that voltage measured at pin 6. If no voltage is obtained replace IC-403_A. If an improper voltage is obtained check the resistor values R216 through 222. Under normal conditions the voltage at pin 6 of IC-403_A will be approximately 2 volts and the voltage at pin 2 approximately 4 volts.

Operation of the positive and negative hit threshold detectors may be verified by observing their output (pin 2, pin 12 respectively) on an oscilloscope with the ± DB switch set at ± 2 dB. The INPUT BRIDGE/600 OHM switch may be used to cause increases and decreased in the signal level. An increase in signal level should cause the output of $IC\text{-}404_A$ to change from - 15 volts to + 15 volts. If this is not observed replace IC-404. A decrease in signal level of 2 dB or greater will cause the output of the negative hits detector $IC\text{-}404_B$ to change from - 15 to + 15 volts DC. If this does not occur replace IC-404. The detector outputs are combined by diodes D410, 411 and are connected to the Time Out Board where Q501 clamps C501 to ground when no hits are detected. Verify with an oscilloscope that C501 charges toward -15 VDC during a hit period. If this does not occur, replace Q501. When the hit duration has exceeded 4.0 milliseconds, the output of $IC\text{-}501_B$ will change from -15 volts to +15 volts for the remainder of each hit duration. If this does not occur, replace IC-501.

5.3.3.8 PHASE/AMPLITUDE COINCIDENT DETECTOR

The coincident detector consists of Q402 which functions as an "and" gate which has a negative going output only when both the phase and amplitude inputs are positive.

Set up the test conditions described in paragraph 5.2.6 and verify that -15 to +10 volt logic pulses are applied to the base of Q402 and 0 to +10 volt pulses are applied to the base of Q113. Verify that 0 to -10 volt pulses appear across D412. If no pulses are seen replace Q402, 113.

5.3.3.9 DROP-OUT DETECTOR

The drop-out detector consists of the long-time constant peak detector Q420, 419 and the threshold detector IC-103B.

With a 0 dB input signal approximately +4 volts should be measured at pin 9 of IC-103B. With a -20 dBm input signal approximately 0.25 volts should be measured. If these voltages are incorrect replace Q419, 420. When adjusted for a drop-out threshold of -18 dB the voltage measured at pin 8 of IC-103B should be approximately 0.25 volts. Using an oscilloscope or volt meter verify that when the input signal is removed the output (pin 12) of IC-103B changes from -15 to +15 volts DC. If this change is not seen replace IC-103.

When the output of IC-103 changes from - to + 15 volts the voltage at the junction of Q403 and R437 should change from 0 to -10 volts. If this is not seen replace Q403.

5.3.3.10 TIMER

The operation of the mechanical counters or the indicating lights is controlled by the mechanical timer S202. To verify its operation place a DC voltmeter between ground and pin 45-K. Verify that approximately 28 volts DC is present when the timer is in the ON or HOLD position. If no voltage is seen check timer S202, transformer T202 and diodes D119 throught 122.

5.3.3.11 COUNTER DRIVERS

Multivibrator circuit values are arranged to provide an "on" time of 50 milliseconds. The following procedure may be used for any of the counter drivers. A negative spike multivibrator trigger input of 15 volts should be observed at the anode of D113. The output may be observed at the base of Q109 with an oscilloscope to measurements proper "on"

and "off" pulse durations. This pulse is amplified in Q109 and drives Q110 which actuates the totalizer. A multitester may be used to measure the dc supply voltage from the bridge rectifier D115 through D118 which should be between 25 and 30 volts DC.

5.3.3.12 POWER SUPPLY

The power supply provides regulated +15 vdc and -15 vdc. These voltages may be verified using a multitester and should be within ±0.5 volts. Improper output voltages may be caused by excessive current drain due to a failure elsewhere in the unit. This can be determined by temporarily disconnecting the supply leads from pins 1 and 10 and remeasuring the supply voltages. Normal loading may be simulated by a 170 ohm 2 watt resistor connected to ground.

If proper voltages are not obtained from the power supply, check diodes D311, 312 for shorts. Verify that +28 vdc is present at the junction of D301, 302 and R311 and -28 vdc at D303, 304, and R301. If this is not obtained check transformer T301, diodes D301 thru 304, and capacitors C301, 302.

If the previous checks are satisfactory each transistor, diode, and resistor must be individually checked. Components associated with the -15 vdc regulator section should be measured first followed by those of the +15 vdc regulator.

5.3.4 CALIBRATION

The following procedures are used to recalibrate the test tone output frequency, the input/output level monitor meter, the reference oscillator frequency, the peak-to-peak and average phase jitter circuits and the phase impulse counter. Recalibration is normally

required when maintenance has been performed on circuitry which will affect the instruments operation or when there is reason to suspect the calibration is no longer accurate.

5.3.4.1 TEST TONE OUTPUT FREQUENCY

a. Connect an electronic counter capable of measuring 1000 kHz to the OUTPUT terminals.

b. Adjust the output LEVEL control until the counter is operating consistently.

c. Adjust L102 (printed circuit board mounted inductor) to give an output frequency of 1,000 kHz ±1 Hz.

5.3.4.2 INPUT/OUTPUT LEVEL METER

a. Connect the test tone OUTPUT terminals to the INPUT terminals.

b. Adjust output LEVEL control for a 0 dBm reading in the 600 OHM position.

c. Connect a standard reference meter in paralled with the INPUT terminals. Be sure all ground connections are properly made.

d. Select the value of R203 (located on S204) to provide an indication within 0.25 dB of the reference meter.

5.3.4.3 REFERENCE PHASE LOCKED OSCILLATOR FREQUENCY

a. Connect a 0 dBm input signal at a frequency of 1,000 kHz to the input terminals.

b. Adjust the LEVEL SET control in accordance with Section 3.3.2

c. Place the FREQ control at its mid-range position (indicator dot straight up)

d. Adjust L101 (printed circuit board mounted inductor) to give a meter reading at the FREQ SET mark with the meter switch in the FREQ position. L101 is adjusted using a small screwdriver to turn the adjustor slug reached through the hole in the center of the core assembly.

5.3.4.4 PEAK-TO-PEAK AND AVERAGE PHASE JITTER

a. The peak-to-peak and average phase jitter ranges are calibrated using a two tone audio technique where the phase jitter is proportional to the level difference between the two tones.

b. To perform this calibration, two audio oscillators having 1% or less harmonic distortion are connected using the resistive network shown in Figure 5-1. Precision resistors of 1% tolerance are required for this network.

c. Turn oscillator #2 level to minimum and adjust the #1 oscillator to provide 0 dBm at a frequency of 1 kHz (±5 cycles) at the INPUT of the Model 45. Measure the level of oscillator #1 across its output terminal using a level meter or a selective voltmeter.

d. Adjust the frequency of oscillator #2 to 1030 Hz (±5 Hz).

e. Using the voltmeter, adjust the oscillator #2 level at its output so that it is 20 dB below the output of oscillator #1 as measured at its output terminals (as shown in Table 5-3).

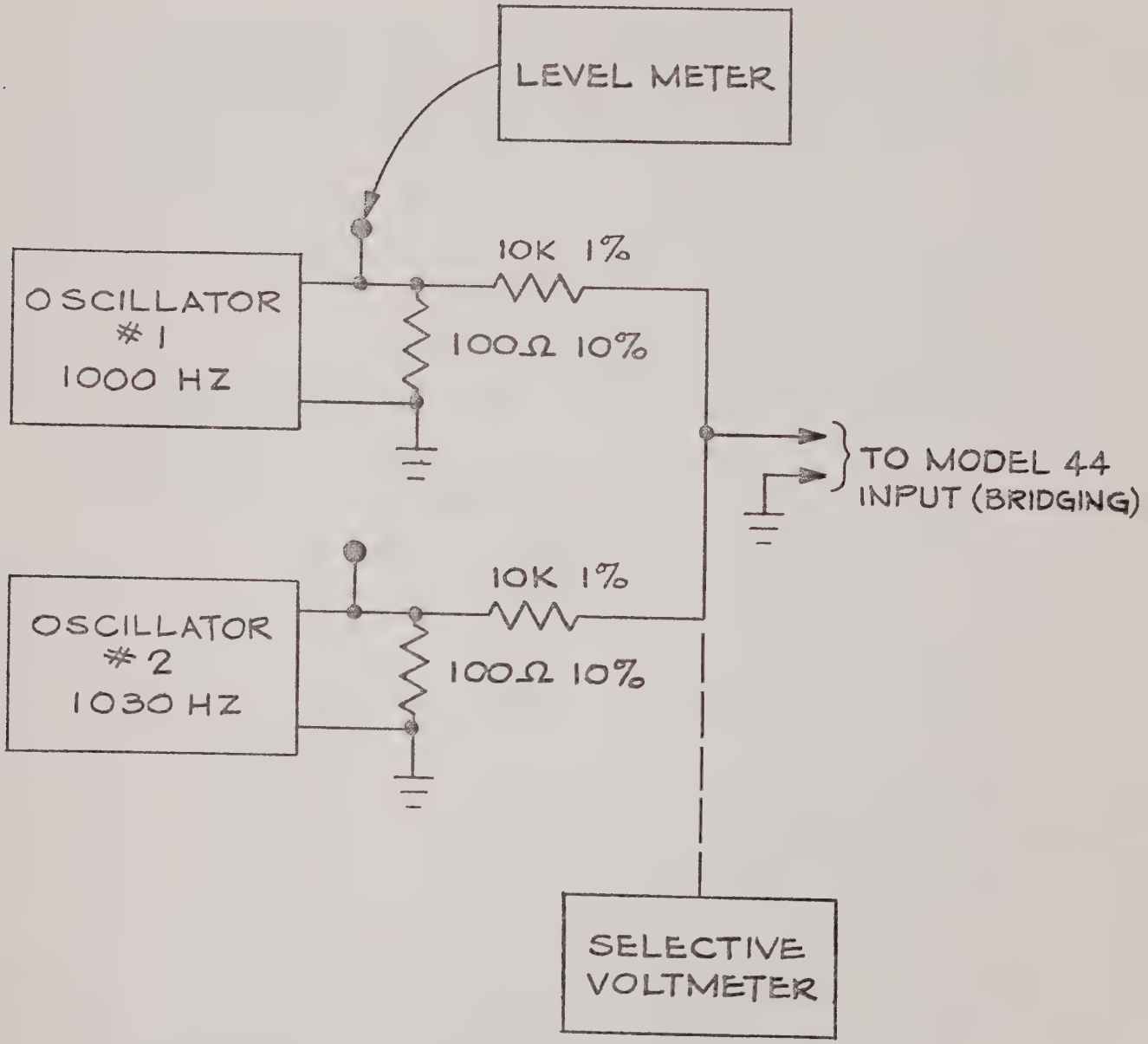

FIGURE 5-1 CALIBRATION BLOCK DIAGRAM

TABLE 5-3

PHASE JITTER CALIBRATION CHART

Level Difference Between Osc. 1 and Osc. 2	JITTER		
	Peak-to-peak	Peak	Average
20.0 dB[1]	11.5°	5.7°	3.6°
11.7 dB[2]	30.0°	15.0°	9.6°

1. Used for peak-to-peak jitter calibration (R146).
2. Used for average jitter and phase impulse counter calibration (R139 and R148).

f. Adjust the FREQ control of the Model 45 for the "locked" condition and read the value of peak-to-peak phase jitter. If this differs by more than 1.0 degree from 11.5 degrees, readjust R145 to provide the proper meter reading.

g. Readjust audio oscillator #2 for a level of 11.7 dB below oscillator #1. The average jitter indication should be within 1.0 degree of 9.2 degrees. If this is not the case, readjust R139 to provide the proper meter reading.

NOTE

The Model 45 test tone oscillator may be used as oscillator #1. However, the use of two external oscillators is recommended.

5.3.4.5 PHASE IMPULSE DETECTOR

a. Calibration of the phase impulse detector is made in a similar manner to that of the phase jitter calibration. The calibration arrangement shown in Figure 5-1 is used.

b. Repeat steps a through d and f of Section 5.3.4.4.

c. Place the DEGREES switch in the 15° position, and place in the timer in the HOLD position.

d. Adjust oscillator #2 for a level 11.7 dB below oscillator #1.

e. Connect an oscillator to terminal M of the HLI-44 board.

f. Adjust R148 so that pulses from +15 volts to -15 volts just begin to appear.

5.3.4.6 AMPLITUDE HITS

The calibration of the threshold levels of the amplitude hits detector is fixed by the resistor values R219 through 222, 425, 426 and no calibration adjustments are provided. It is necessary, however, to adjust the automatic level control circuitry for optimum operation in accordance with the following procedures.

a. Using a 1.0 kHz test-tone input properly adjust the LEVEL SET control.

b. Connect a DC voltmeter to the junction of D409, C411.

c. Adjust potentiometer R418 for a positive voltage reading of 2.5 volts DC. Wait approximately 10 to 15 seconds before reading the voltmeter to allow the long-time constant circuitry to come to its final value.

5.3.4.7 DROP-OUT THRESHOLD

a. Adjust the instrument in accordance with paragraph 5.2.2.

b. Without readjusting the LEVEL SET control lower the input level 18 dB. The internal level meter may be used or more accurate readings may be obtained with an external reference voltmeter connected across the input terminals.

c. Using an oscilloscope or voltmeter monitor the voltage at the dropout logic output (TB 203)/

d. Adjust the potentiometer R-434 to cause a change in the output level (either 0 or -10 volts). Set R-434 at the position which cause the level to change from 0 to -10 volts.

TABLE 5-4 MAIN FRAME PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
5-2	D201, 202	Diode, germaniam, 1N191	--	GE
	DS-201 thru DS-205	Pilot Lamp Incandesent 28V, .040 amp	327	Chicago Lamp
		Pilot Lamp Assy (Yellow)	162-8430-0933-582 MS 25 256-2	Dialco
	DS-206	Pilot Lamp Neon NE-2D		Chicago Lamp
	L203 thru L206	Totalizer, 24 VDC, 4 digit	TCeZ4E	Sodeco
	M201	Meter, 0-50 Microamp	44-001	HLI
	R201	Resistor: fixed, composition, 620 ohm, ±5%, 2w	--	Ohmite
	R202	Resistor: variable, carbon, 10K, ±10%, 1/2w	ASM	Ohmite
	R203	Resistor: fixed, composition, selected valve, ±5%, 1/4w		Ohmite
	R204, 205	Resistor: fixed, composition, 10K, ±5%, 1/4w		Ohmite
	R206 thru R214	Resistor: fixed, composition, 150 ohms, ±1%, 1/4w	RN60D	IRC
	R215	Resistor: variable, carbon, 10K, ±10%, 1/2w	ASM	Ohmite
	R216	Resistor, fixed, deposited, 576 ohm, ±1%, 1/4w	RN60D	IRC
	R217	Resistor, fixed, deposited 154 ohm, ±1%, 1/4w	RN60D	IRC
	R218	Resistor, fixed, deposited, 137 ohm, ±1%, 1/4w	RN60D	IRC
	R219	Resistor, fixed, deposited, 97.6 ohm, ±1%, 1/4w	RN60D	IRC

TABLE 5-4 MAIN FRAME PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
5-2	R220	Resistor, fixed, deposited, 86.6 ohm, ±1%, 1/4w	RN60D	IRC
	R221	Resistor, fixed, deposited, 205 ohm, ±1%, 1/4w	RN60D	IRC
	R222	Resistor, fixed, deposited, 499 ohm, ±1%, 1/4w	RN60D	IRC
	R223	Resistor: variable, carbon, 100K/100K, ±10%, 2w	CCU	Ohmite
	R224	Resistor, fixed, composition, ~~610~~ 910 ohm, ±5%, 2w (Part Spec)	--	Ohmite
	R225	Resistor, fixed, composition, 27K, ±5%, 1/4w		Ohmite
	S201	Switch, toggle, 1 pole, 2 position	MST 115D	Alco
	S202	Switch, timer, 60 min. with hold, 1 pole, 1 position	90024	M.H. Rhodes
	S203	Switch, push, 1 pole, 2 position	616	Marco-Oak
	S204	Switch, rotary, 4 pole, 6 position	PA1015	Centralab
	S205	Swithc, rotary, 1 pole, 9 position	PA1000	Centralab
	S206	Switch, rotary, 2 pole, 4 position	PA1002	Centralab
	S207	" , TOGGLE	MST-415N	Alco
	T201	Transformer, power	P8395	Stancor

TABLE 5-5 PHASE JITTER DETECTOR BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
5-3	C101, 102	Capacitor, paper, .22 mfd, 200 VDC (Not used in Model 45)	2PS-P22	Sprague
	C103	Capacitor, ceramic, .01 mfd, 50 VDC	HY	Sprague
	C104	Capacitor, electrolytic, 50 mfd, 25 VDC	30D	Sprague
	C105	Capacitor, paper, .15 mfd, 75 VDC	225PZ	Sprague
	C106	Capacitor, paper, .018 mfd, 100 VDC	225PW	Sprague
	C107	Capacitor, ceramic 47 pf, 1000 VDC	5GA	Sprague
	C108	Same as C107		
	C109	Capacitor, tantilum, 22 mfd, 15 VDC	TAS	Mallory
	C110	Capacitor, paper, .22 mfd, 75 VDC	225PZ	Sprague
	C111	Same as C109		
	C112	Same as C107		
	C113, 114	Same as C103		
	C115	Same as C107		
	C116	Same as C103		
	C117	Same as C107		
	C118	Same as C103		
	C119	Same as C107		
	C120, 121	Same as C104		

TABLE 5-5 PHASE JITTER DETECTOR BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
5-3	C122	Capacitor, ceramic, .001 mfd, 600 VDC	5GA	Sprague
	C123	Same as C110		
	C124	Capacitor, ceramic, 2.2 mfd, 20 VDC	5CO	Sprague
	C125	Capacitor, paper, .039 mfd, 100 VDC	225W	Sprague
	C126	Capacitor, paper, .027 mfd, 100 VDC	225W	Sprague
	C127	Capacitor, paper, .01 mfd, 100 VDC	225W	Sprague
	C128	Capacitor, paper, selected valve, 100 VDC	225W	Sprague
	C129	Same as C105		
	C130	Same as C107		
	C131	Same as C110		
	C132, 133	Same as C110		
	C135	Capacitor, paper, .2 mfd, 200 VDC	220P	Sprague
	C136, 137	Same as C103		
	C138, 139	Capacitor, electrolytic, 150 mfd, 16 VDC (Not used in Model 44)	30D	Sprague
	C140	Same as C106		
	D101 thru D104	Diode, Silicon, 1N3064 (Not used in Model 45)	--	Fairchild
	D105,106	Diode, Silicon, 1N3064	--	Fairchild

TABLE 5-5 PHASE JITTER DETECTOR BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
5-3	D107, 108	Diode, zener, 1N706A	--	Motorola
	D109 thru D114	Same as D105		
	D115 thru D118	Diode, silicon, 1N2482	--	Sarkes-Tarzian
	D119 thru 121	Same as D105		
	IC 101 thru IC 104	Integrated circuit, dual amplifier	MC-1437L or TOA 2809	Motorola Transistron
	L101, 102	Inductor, Pot Core (adj.), 0.1 mhy	44-008	HLI
	Q101 thru 107	Transistor, silicon, 2N3566	--	Fairchild
	Q108	Transistor, silicon, 2N5138	--	Fairchild
	Q109	Same as Q101		
	Q110	Transistor, silicon, 2N3440	--	RCA
	Q111	Same as Q101		
	R101	Same as R103		
	R103	Resistor: fixed, composition, 10K, ±5%, 1/4w	--	Ohmite

TABLE 5-5 PHASE JITTER DETECTOR BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
5-3	R104	Resistor: fixed, composition, 100K, ±5%, 1/4w	--	Ohmite
	R105	Same as R103		
	R106	Resistor: fixed, composition, 2.2K, ±5%, 1/4w	--	Ohmite
	R107	Resistor: fixed, composition, 47K, ±5%, 1/4w	--	Ohmite
	R108	Resistor: fixed, composition, 4.7K, ±5%, 1/4w	--	Ohmite
	R109	Same as R107		
	R110	Same as R108		
	R111	Same as R103		
	R112	Resistor: fixed, composition, 1.0K, ±5%, 1/4w	--	Ohmite
	R113	Resistor: fixed, composition, 13K, ±5%, 1/4w	--	Ohmite
	R114	Resistor: fixed, composition, 6.8K, ±5%, 1/4w	--	Ohmite
	R115	Resistor: fixed, composition, 13K, ±5%, 1/4w	--	Ohmite
	R116	Same as R106		
	R117	Resistor: fixed, composition, 2.7K, ±5%, 1/4w	--	Ohmite
	R118	Resistor: fixed, composition, 220K, ±5%, 1/4w	--	Ohmite
	R119	Resistor: fixed, composition, selected value, ±5%, 1/4w	--	Ohmite
	R120	Same as R103		
	R121	Resistor: fixed, composition, 27K, ±5%, 1/4w	--	Ohmite

TABLE 5-5 PHASE JITTER DETECTOR BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
5-3	R123	Same as R106		
	R124	Resistor: fixed, composition, 12K, ±5%, 1/4w	--	Ohmite
	R125	Resistor: fixed, composition, 27K, ±5%, 1/4w	--	Ohmite
	R126	Resistor: fixed, composition, 22K, ±5%, 1/4w	--	Ohmite
	R127	Resistor: fixed, deposited, 10K, ±1%, 1/4w	RN60D	IRC
	R128	Same as R108		
	R129	Same as R127		
	R130	Same as R127		
	R131	Resistor: fixed, deposited, 20K, ±1%, 1/4w	RN60D	IRC
	R132	Same as R127		
	R133	Same as R106		
	R134	Same as R103		
	R135	Resistor: fixed, composition, 6.8K, ±5%, 1/4w		Ohmite
	R136	Same as R131		
	R137	Same as R106		
	R138	Resistor: fixed, composition, 68K, ±5%, 1/4w	--	Ohmite
	R139	Resistor: variable, wirewound, 20K, ±10%, 1/2w	89PR203	Helipot
	R140	Same as R103		
	R141	Same as R126		

TABLE 5-5 PHASE JITTER DETECTOR BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
5-3	R142	Same as R106		
	R143, 144	Same as R104		
	R145	Same as R139		
	R146	Same as R138		
	R147	Same as R106		
	R149	Same as R112		
	R148	Resistor: variable, wirewound, 1.0K, ±10%, 1/2w	89PR102	Helipot
	R150	Resistor: fixed, composition, 1.8K, ±5%, 1/4w	--	Ohmite
	R151	Same as R126 (Not used in Model 45)	--	Ohmite
	R152	Same as R127 (Not used in Model 45)	--	Ohmite
	R153	Resistor: fixed, composition, 120K, ±5%, 1/4w	--	Ohmite
	R155	Same as R126		
	R156	Same as R104		
	R157	Same as R135		
	R158, 159	Same as R126		
	R160	Same as R108		
	R161	Same as R104		
	R162	Same as R104		

TABLE 5-5 PHASE JITTER DETECTOR BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
5-3	R163	Same as R107		
	R164, 165	Same as R103		
	R166, 167	Same as R104		
	R168	Same as R106		
	R170, 171	Resistor: fixed, composition, 560Ω, ±5%, 1/4w	--	Ohmite
	R172, 173	Same as R104		
	R174, 175, 176	Same as R106		
	R177	Same as R112		
	R178	Same as R108		
	R179, 180	Resistor: fixed, composition, 100Ω, ±5%, 1/4w	--	Ohmite
	R181	Resistor: fixed, composition, 2.2 meg., ±5%, 1/4w	--	Ohmite
	T101	Transformer, audio	DCM9-PC	Microtran

TABLE 5-6 AMPLITUDE DETECTOR BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
5-5	C401, 402	Capacitor, paper, .22 mfd, 200 VDC	2PS-P22	Sprague
	C403	Capacitor, ceramic disc, 47 PF, 1000 VDC	5GA-Q47	Sprague
	C404	Capacitor, ceramic disc, ~~.01~~ .01, 50 VDC	HY	Sprague
	C405	Capacitor, electrolytic, ~~5.0~~ 6.0, mfd, 25 VDC	30-D	Sprague
	C406	Same as C404		
	C407	Same as C403		
	C408	Capacitor, electrolytic, 50 mfd, 25 VDC	30-D	Sprague
	C409	Same as C404		
	C410	Same as C403		
	C411, 412	Capacitor, paper, .22 mfd, 75 VDC	225P	Sprague
	C413	Capacitor, paper, .15 mfd, 75 VDC	225P	Sprague
	C414	Capacitor, paper, .018 mfd, 100 VDC	225P	Sprague
	C415	Same as C403		
	C416	Same as C404		
	C417	Same as C408		
	C418	Same as C403		
	C419	Same as C404		
	C420	Same as 408		

TABLE 5-6 AMPLITUDE DETECTOR BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
5-5	C421	Same as C403		
	C422	Capacitor, ceramic disc, .001, 1000 VDC	5GA	Sprague
	C423	Same as C403		
	C424	Same as C422		
	C425	Same as C403		
	C426, 427	Same as C422		
	C428	Same as C411		
	C429	Same as C422		
	C430	Same as C411		
	C431	Same as C422		
	C432	Same as C411		
	C433,434	Same as C411		
	D401 thru D419	Diode, silicon, 1N3064		Fairchild
	IC-401 thru IC-404	Integrated circuit, dual amplifier	MC1437L or TOA 2809	Motorola Transitron
	Q401 thru Q403	Transistor, silicon, 2N5138		Fairchild

TABLE 5-6 AMPLITUDE DETECTOR BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
5-5	Q404	Transistor, silicon, 2N3566		Fairchild
	Q405	Same as Q401		
	Q406	Same as Q404		
	Q407	Transistor, silicon, 2N3440		RCA
	Q408	Same as Q404		
	Q409	Same as Q401		
	Q410, 411	Same as Q404		
	Q412	Same as Q407		
	Q413, 414	Same as Q404		
	Q415	Same as Q401		
	Q416, 417	Same as Q404		
	Q418	Same as Q407		
	Q419	Same as Q401		
	Q420	Same as Q404		
	Q421	Transistor, silicon, MPF102	--	Motorola
	R401, 402	Resistor, fixed, composition, 10K, ±5%, 2w		Ohmite
	R403, 404	Resistor, fixed, composition, 4.7K, ±5%, 1/4w	--	Ohmite
	R405	Resistor, fixed, composition, 2.2K, ±5%, 1/4w		Ohmite

TABLE 5-6 AMPLITUDE DETECTOR BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
5-5	R406	Resistor, fixed, composition, 100K, ±5%, 1/4w		Ohmite
	R407	Same as R405		
	R408	Resistor, fixed, composition, 10K, ±5%, 1/4w		Ohmite
	R409 thru R412	Resistor, fixed, deposited, 20K, ±1%, 1/4w	RN60D	IRC
	R413	Resistor, fixed, composition, 51 ohm, ±5%, 1/4w		Ohmite
	R414	Same as R405		
	R415	Resistor, fixed, composition, 51K, ±5%, 1/4w		Ohmite
	R416	Resistor, fixed, composition, 2.2 meg, ±5%, 1/4w		Ohmite
	R417	Same as R406		
	R418	Resistor, variable wire wound, 20K, 10%, 1/2w	89PR203	Helipot
	R419	Resistor, fixed, composition, 3.3K, ±5%, 1/4w		Ohmite
	R420	Resistor, fixed, composition, 16K, ±5%, 1/4w		Ohmite
	R421	Resistor, fixed, composition, 8.2K, ±5%, 1/4w		Ohmite
	R422	Same as R420		
	R423	Same as R405		
	R424	Same as R408		
	R425	Resistor, fixed, deposited, 120 ohm, ±1%, 1/4w	RN60D	IRC

TABLE 5-6 AMPLITUDE DETECTOR BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
5-5	R426	Resistor, fixed, deposited, 110 ohm, ±1%, 1/4w	RN60D	IRC
	R427	Same as R405		
	R428	Resistor, fixed, composition, 1.8K, ±5%, 1/4w		Ohmite
	R429	Same as R416		
	R430	Same as R428		
	R431	Same as R416		
	R432	Resistor, fixed, composition, 6.8K, ±5%, 1/4w		Ohmite
	R433	Resistor, fixed, composition, 300 ohm, ±5%, 1/4w		Ohmite
	R434	Resistor, variable, wire wound, 200 ohm, ±10%, 1/2w	89PR200	Helipot
	R435	Same as R408		
	R436, 437	Same as R403		
	R438	Same as R408		
	R439	Resistor, fixed, composition, 33K, ±5%, 1/4w		Ohmite
	R440	Resistor, fixed, composition, 22K, ±5%, 1/4w		Ohmite
	R441	Same as R406		
	R442	Same as R432		
	R443	Same as R403		
	R444, 445	Same as R440		

TABLE 5-6 AMPLITUDE DETECTOR BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
5-5	R446	Resistor, fixed, comp., 1K, ±5%, 1/4w		Ohmite
	R447	Same as R408		
	R448	Same as R440		
	R449	Same as R403		
	R450	Same as R408		
	R451	Same as R403		
	R452	Same as R408		
	R453	Same as R439		
	R454	Same as R440		
	R455	Same as R406		
	R456	Same as R432		
	R457	Same as R403		
	R458, 459	Same as R440		
	R461	Same as R403		
	R462	Same as R408		
	R463	Same as R403		
	R464	Same as R408		
	R465	Same as R446		

TABLE 5-6 AMPLITUDE DETECTOR BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
5-5	R466	Same as R408		
	R467	Same as R440		
	R468	Same as R403		
	R469	Same as R408		
	R470	Same as R439		
	R471	Same as R440		
	R472	Same as R406		
	R473	Same as R432		
	R474	Same as R403		
	R475, 476	Same as R440		
	R477	Same as R408		
	R478	Same as R403		
	R479	Same as R446		
	R480	Resistor, fixed, composition, 47K, ±5%, 1/4w		Ohmite
	R481	Same as R406		
	R482	Same as R428		
	R483	Same as R416		

TABLE 5-7 POWER SUPPLY PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
5-7	C301, 302	Capacitor, electrolytic, 250 mfd, 25 VDC	45-101	HLI
	C303, 304	Capacitor, ceramic, 180 pf, 600 VDC	JK 180	RMC
	C305, 306	Capacitor, electrolytic, 100 mfd, 25 VDC	45-102	HLI
	D301 thru 304	Diode, silicon, 1N4001		Motorola
	D305	Diode, silicon, 1N4148		Sylvania
	D306	Diode, Zener, 1N751 A		Int. Rect.
	D307 thru D310	Same as D305		
	D311, 312	Same as D301		
	Q301	Transistor, silicon, 38588		RCA
	Q302	Transistor, silicon, 39618		RCA
	Q303	Transistor, silicon, 2N4248		Fairchild
	Q304 thru Q307	Transistor, silicon, 2N3565		Fairchild
	Q308	Same as Q303		
	R301	Resistor, fixed, composition, 4.3 ohm, ±5%, 1/2w		Ohmite
	R302	Resistor, fixed, composition, selected, ±5%, 1/4w		Ohmite
	R303	Resistor, fixed, composition, 1.0K, ±5%, 1/4w		Ohmite

TABLE 5-7 POWER SUPPLY PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
5-7	R304	Resistor, fixed, composition, 2.2K ±5%, 1/4w		Ohmite
	R305	Resistor, fixed, composition, 15K, ±5%, 1/4w		Ohmite
	R306	Resistor, fixed, composition, 1.2K, ±5%, 1/4w		Ohmite
	R307	Resistor, fixed, composition, selected, ±5%, 1/4w		Ohmite
	R308, 309	Resistor, fixed, composition, 680 ohm, ±5%, 1/4w		Ohmite
	R310	Resistor, fixed, composition, selected, ±5%, 1/4w		Ohmite
	R311	Same as R301		
	R312	Same as R302		
	R313	Same as R303		
	R314	Same as R304		
	R315	Resistor, fixed, composition, 10K, ±5%, 1/4w		Ohmite
	R316	Resistor, fixed, composition, selected, ±5%, 1/4w		Ohmite
	R317	Resistor, fixed, composition, selected, ±5%, 1/4w		Ohmite
	R318	Resistor, fixed, composition, 4.7K, ±5%, 1/4w		Ohmite
	R319	Resistor, fixed, composition, 5.1K, ±5%, 1/4w		Ohmite
	T301	Transformer, power	45-103	HLI

TABLE 5-8 TIME OUT BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
5-9	C501, 502	Capacitor, paper, .22 mfd, 75 VDC	225PZ	Sprague
	C503, 504	Capacitor, ceramic, .001 mfd, 600 VDC	5GA	Sprague
	C506, 507	Capacitor, ceramic, 47 pf, 600 VDC	5GA	Sprague
	C508, 509	Same as C501		
	D501 thru 504	Diode, silicon, 1N3064		Fairchild
	IC-501	Integrated circuit, dual amplifier	MC 1437L or TOA 2809	Motorola Transitron
	Q501	Transistor, silicon, 2N5138		Fairchild
	Q502	Transistor, silicon, 2N3566		Fairchild
	R501,502	Resistor, fixed, composition, 22K, ±5%, 1/4w		Ohmite
	R503, 504	Resistor, fixed, composition, 10K, ±5%, 1/4w		Ohmite
	R505	Resistor, fixed, composition, 100Ω, ±5%, 1/4w		Ohmite
	R506	Resistor, fixed, composition, 100K, ±5%, 1/4w		Ohmite
	R507, 508	Same as R501		
	R509, 510	Same as R503		
	R511	Same as R505		
	R512	Same as R506		
	R513	Same as R501		

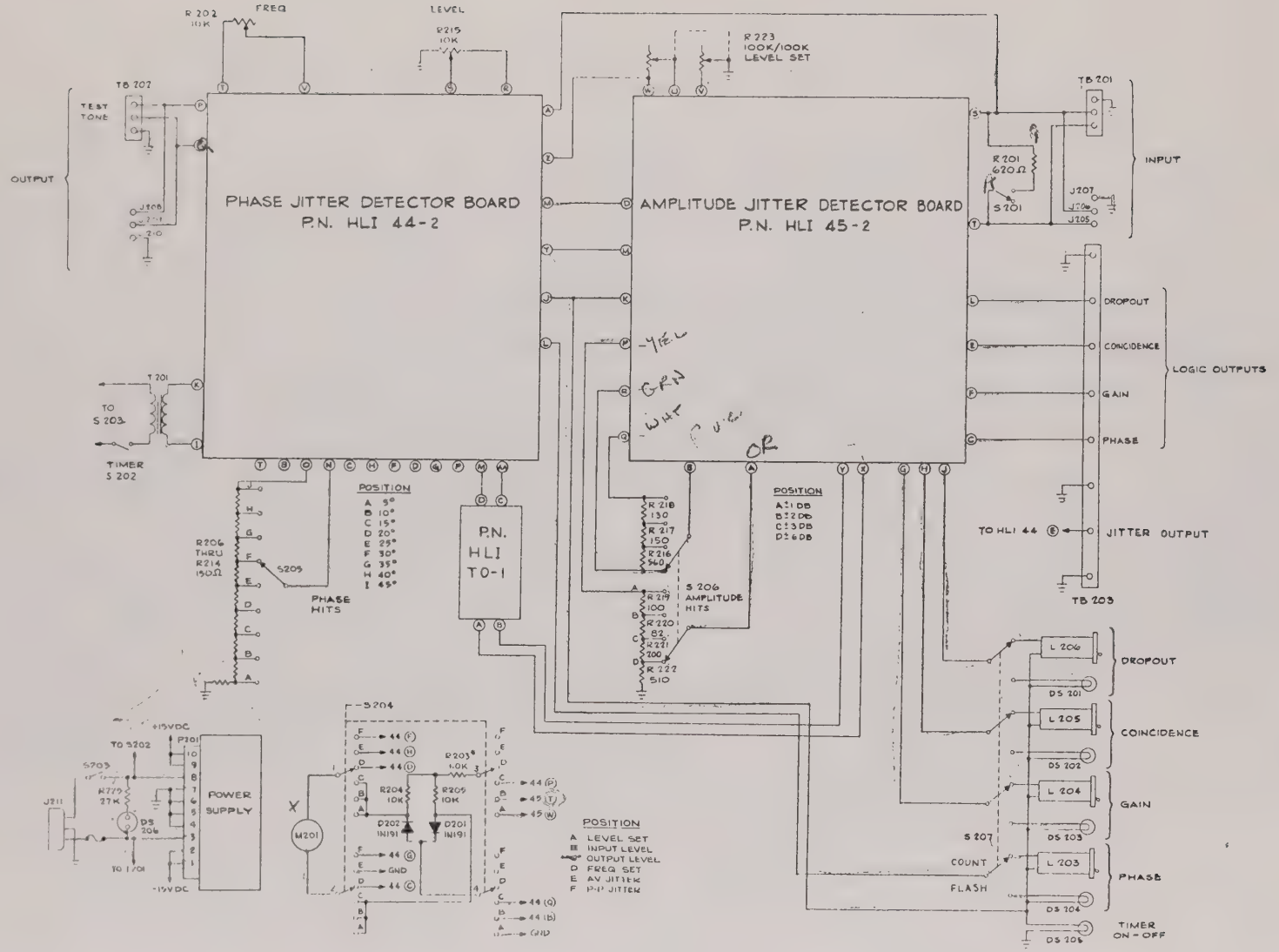

FIGURE 5-2 MODEL 45 WIRING DIAGRAM

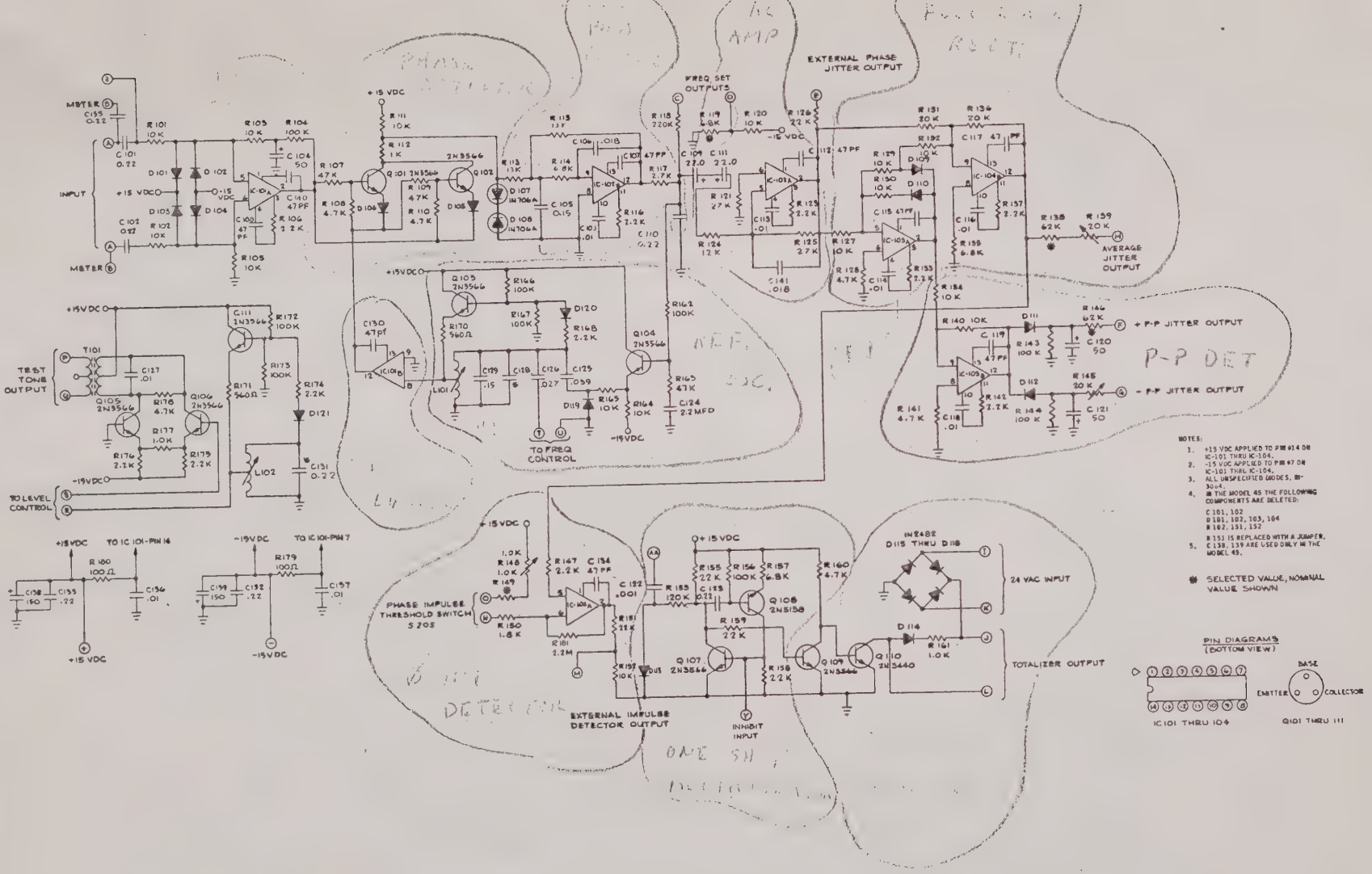

FIGURE 5-3 PHASE JITTER DETECTOR BOARD SCHEMATIC DIAGRAM

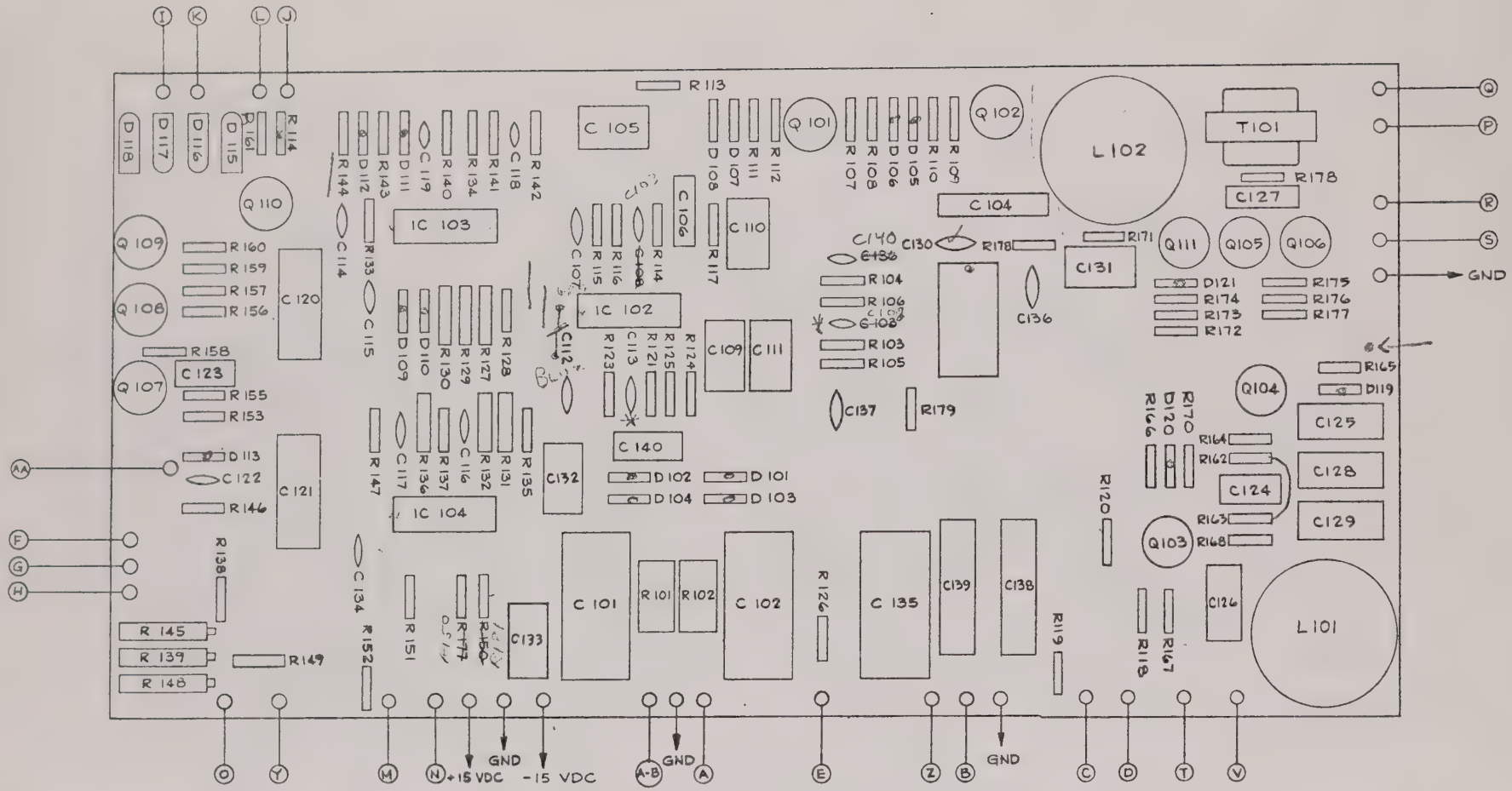

FIGURE 5-4 PHASE JITTER DETECTOR BOARD COMPONENT LAYOUT

BRN GRN R BL
R BLU BRN GR
O W VIO

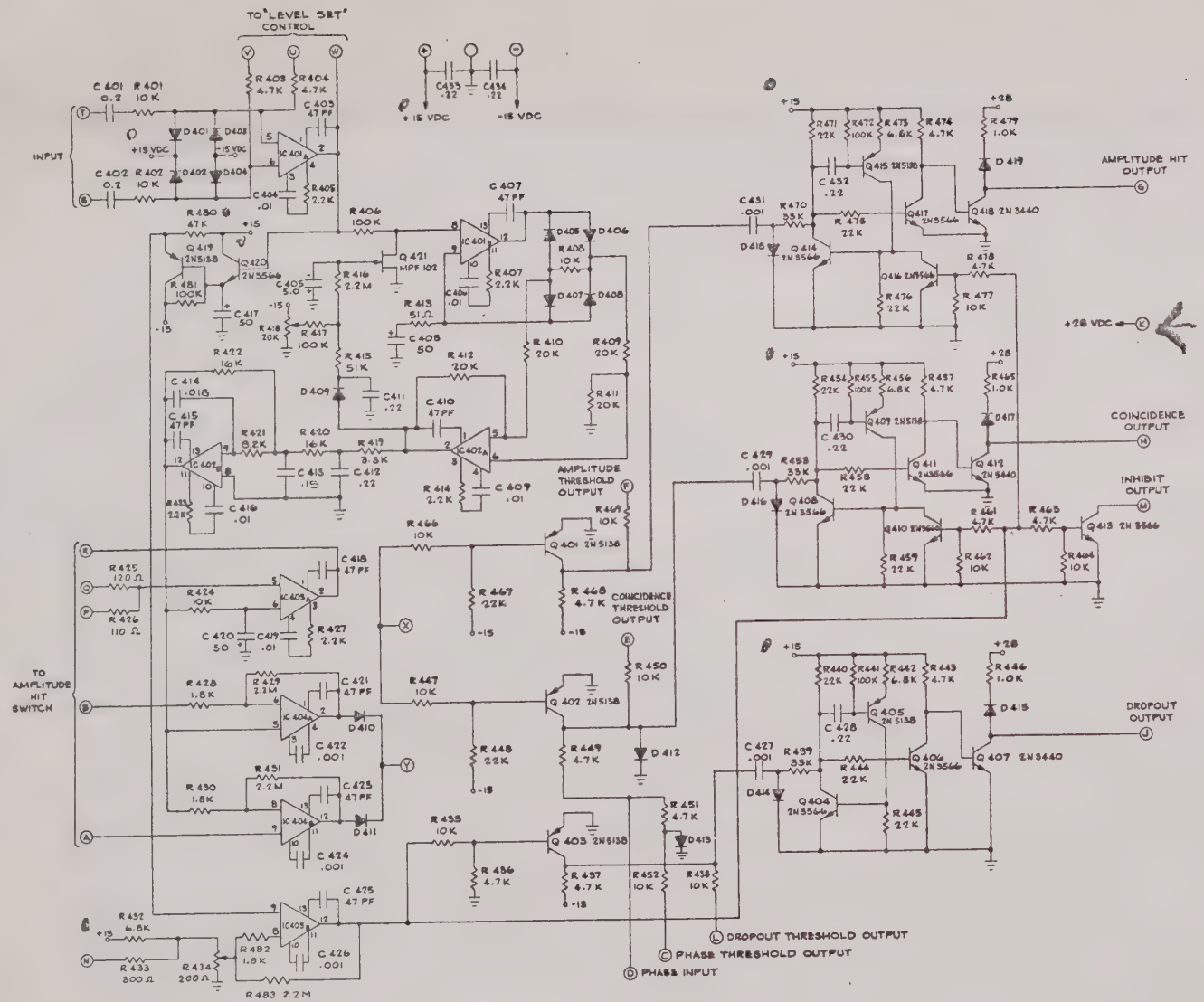

FIGURE 5-5 AMPLITUDE DETECTOR BOARD SCHEMATIC DIAGRAM

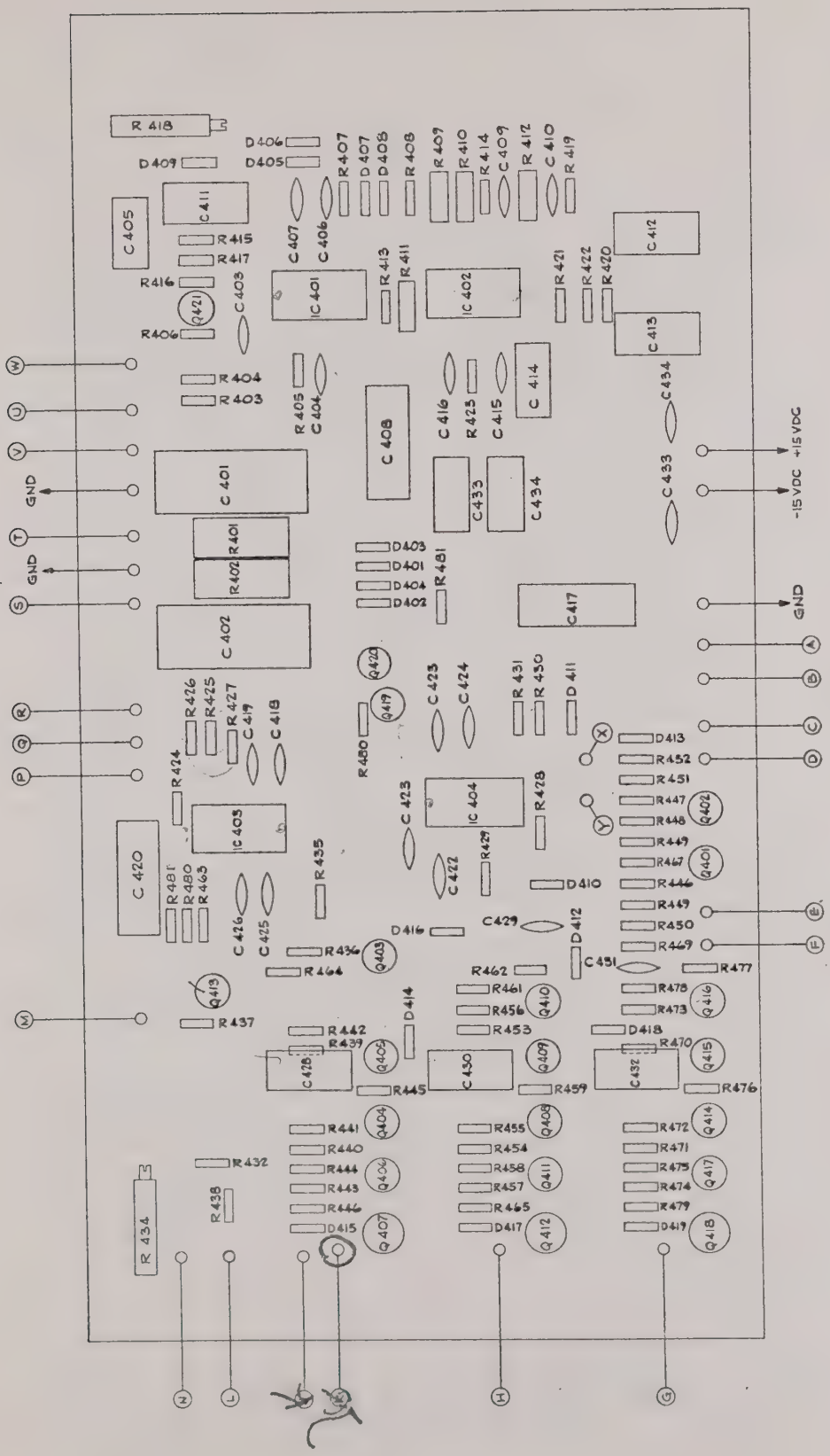

FIGURE 5-6 AMPLITUDE DETECTOR BOARD COMPONENT LAYOUT

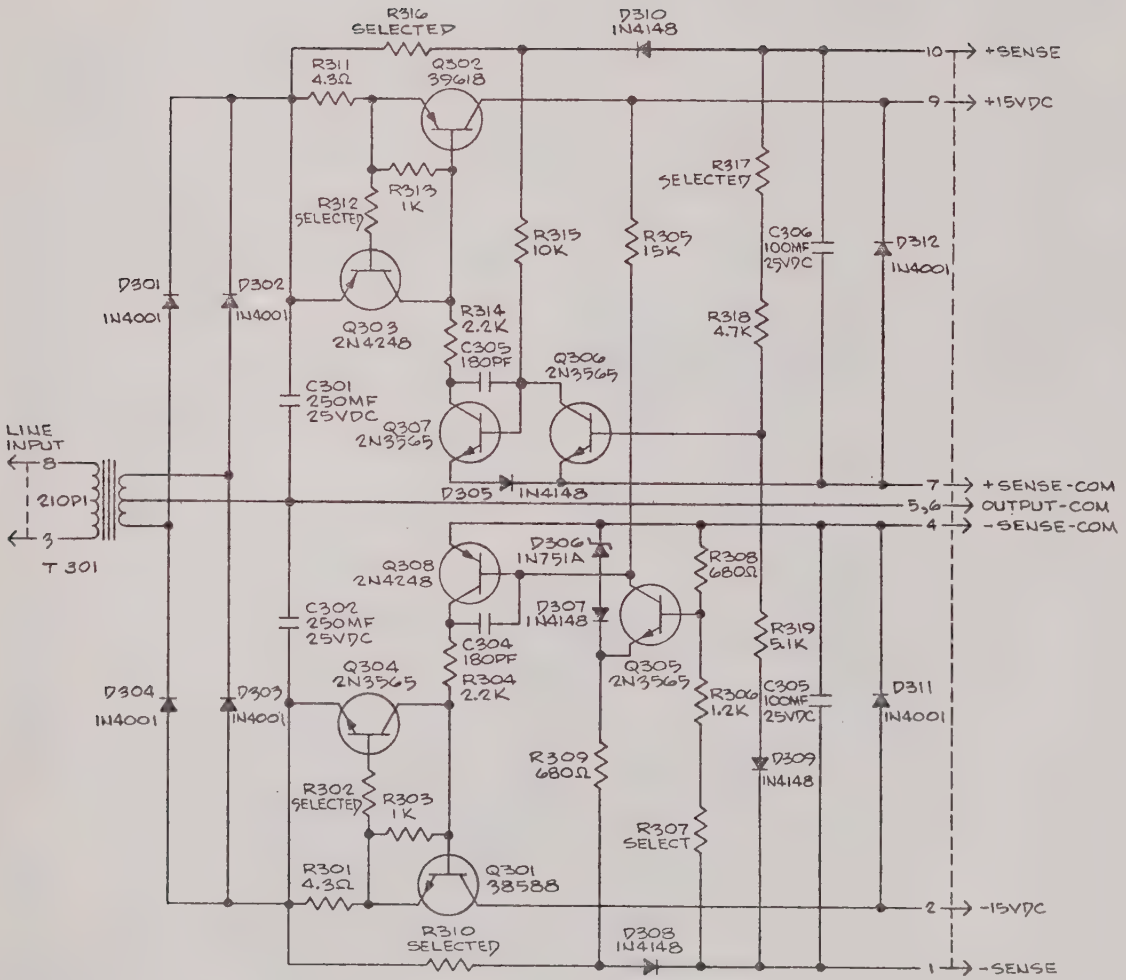

FIGURE 5-7 POWER SUPPLY SCHEMATIC DIAGRAM

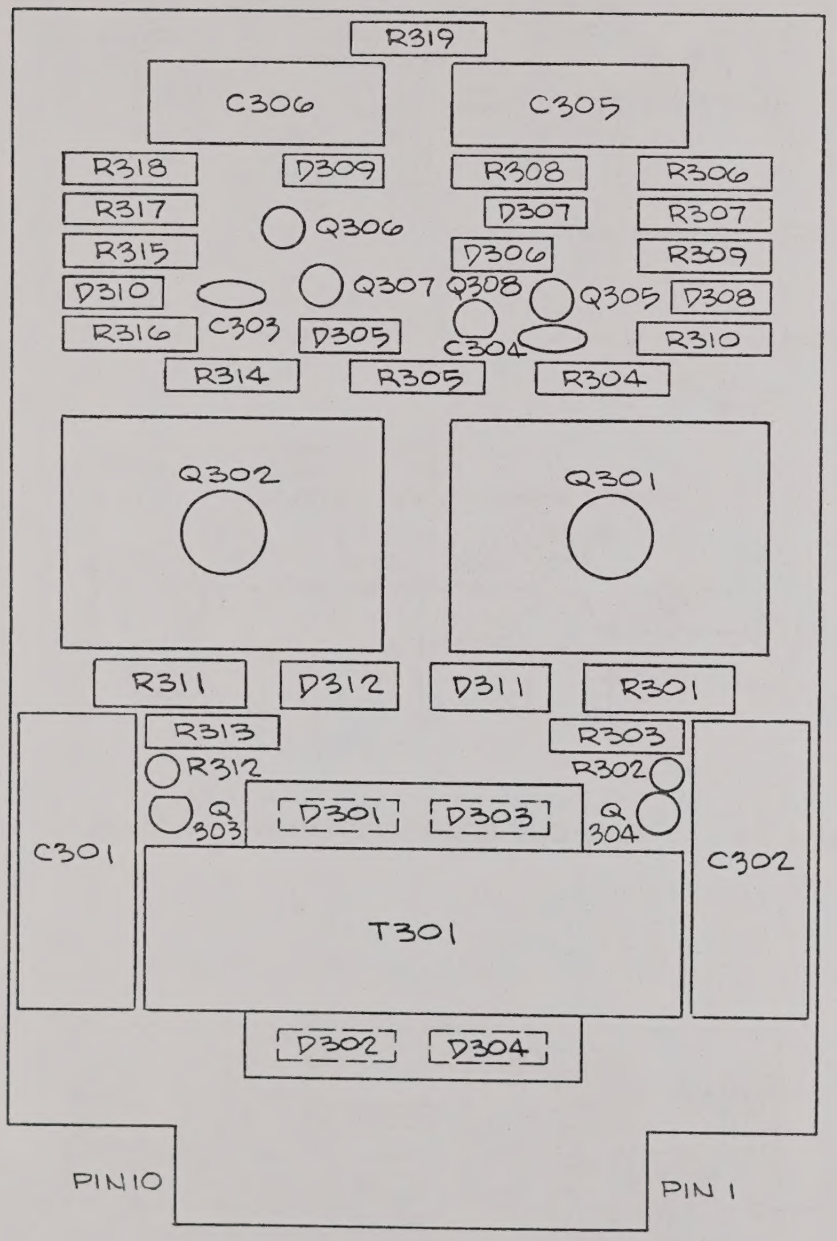

FIGURE 5-8 POWER SUPPLY BOARD COMPONENT LAYOUT

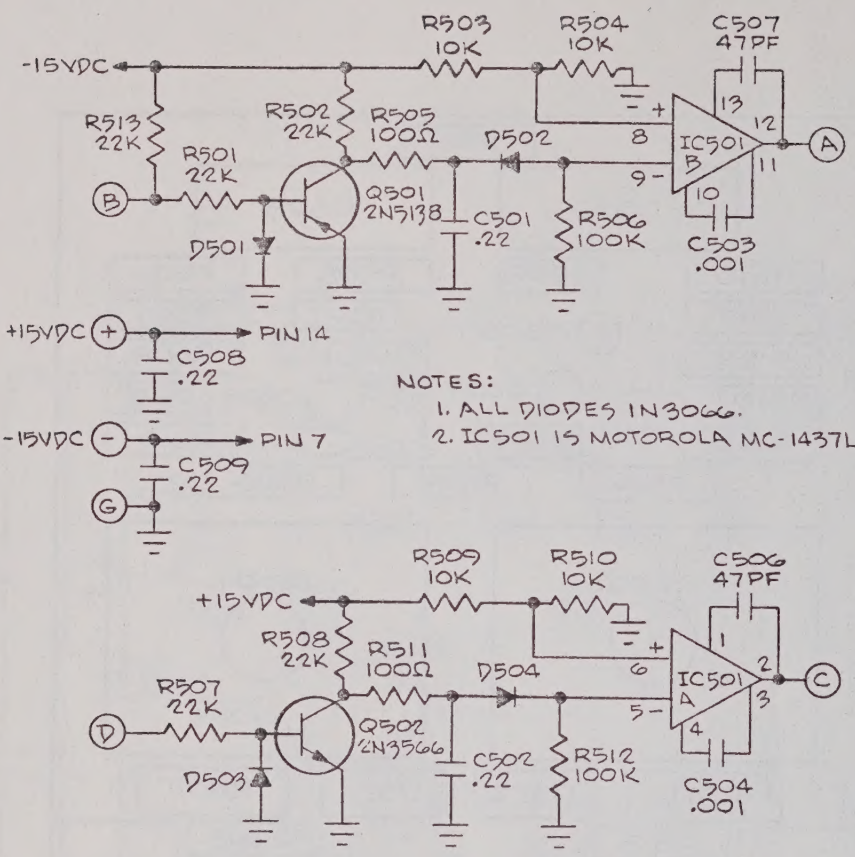

FIGURE 5-9 TIME OUT BOARD SCHEMATIC DIAGRAM

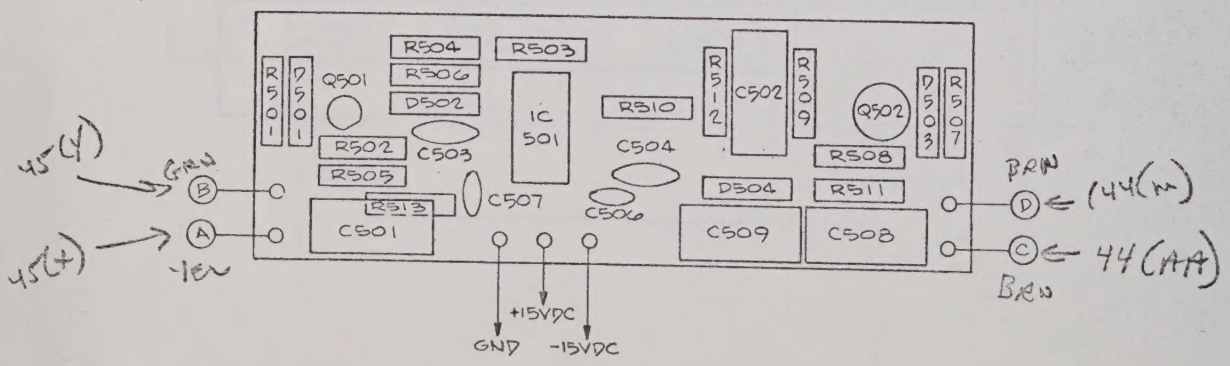

FIGURE 5-10 TIME OUT BOARD COMPONENT LAYOUT